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THE INFLUENCE OF CERTAIN PUBLIC HEALTH PROCEDURES UPON INFANT MORTALITY[1]

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OBJECTIVES

IN THE first volume of his reminiscences, Newsholme (1935) has forcibly pointed out the difficulties and dangers inherent in the attempt to analyze the rôle of a particular health procedure in producing a specific lowering of the infant death rate. He says, "Public health workers are beset with demands to show results of their work — to 'produce the goods' to use a common phrase. Sometimes in public health work this can be done, more often not." In one of his reports nearly twenty years ago he had stated that "It cannot be too constantly borne in mind that, when complex causes are in operation, to attempt by statistics to prove the influence of one of these is likely to lead to serious errors."

We fully appreciate the force of this argument and would, with Newsholme, deprecate any conclusion that, in such a complex problem, the failure to demonstrate a specific influence implied that no such influence existed. Yet we have felt that, in spite of the difficulties involved, the time was perhaps ripe for a study of the relationship between certain

[1]Financed in part through a grant from the Commonwealth Fund.

public health procedures and infant mortality rates in American cities. There are two reasons why it seemed that such an investigation would be profitable. Negative results might only prove that the factors were too complex, and the available data insufficient, to demonstrate a relationship which — on grounds of common sense and clinical experience — we may be sure exists; but positive results, if obtained, would be all the more valuable on account of the difficulties involved. Furthermore, any careful analysis of such a problem can scarcely fail to throw light on the statistical pitfalls involved and must at least aid us in avoiding false claims based on an inadequate analysis of the factors concerned. We have therefore here attempted to determine whether the influence of two outstanding public health procedures, the pasteurization of milk and the provision of infant welfare clinic service, could be shown by sound statistical analysis to have had specific demonstrable influence upon the infant mortality rate of certain American cities.

CRITERIA OF INFANT MORTALITY IN AMERICAN CITIES

As a preliminary to our more intensive study, it seemed desirable to obtain a picture of the long-time trends of infant death rates in certain American cities as a background. After some searching of the records, nine cities — Baltimore, Boston, Chicago, Hartford, New Haven, New Orleans, New York City (the Former City, including only the boroughs of Manhattan and the Bronx), Philadelphia and Providence — were selected, on the basis of the availability of local statistics on infant deaths for a period of fifty years.

Defective birth registration has persisted in certain of these cities until recent years. Thus, Chicago was included in the United States Birth Registration Area only in 1922, and New Orleans, in 1927. Howard (1924) states that in Baltimore, while birth registration was required by law in 1875, "before 1912 the health department made no consistent efforts to enfore this law", and "birth registration was very defective until 1915." In New York City, "births were not reported in their entirety until 1910."[7] Birth registration in Philadelphia was probably defective also until 1910. In Hartford and New Haven, birth registration has been 90 per cent complete since 1900, and reached 98 per cent completeness in 1920.[8]

Birth registration probably approached completeness in Boston at an earlier date than in the other cities of this group. Glover's (1921) check of birth regis-

[7]Annual Report, Department of Health, *City of New York*. 1920.

[8]Personal Communication from Director, Bureau of Vital Statistics of Connecticut Department of Health.

tration by a comparison of computed and registered births indicated that birth registration in Boston was adequate in the period 1900-1902, the rates of mortality in the life tables for Boston in 1901 being based on the number of registered births.

In the absence of accurate birth statistics for these cities over a long period of years, it was not possible to use the infant mortality rate (death of infants under one year of age per 1000 live births) as a measure of infant mortality throughout the entire period. It was necessary, therefore, to relate the deaths under one year of age to the estimated population under one, derived from the census returns for this age group in the census enumerations from 1880 through 1930. While census enumeration of children under one year of age is also incomplete, the deficiency in the census returns appears to have been somewhat constant for each of the last six censuses with the exception of the census of 1890. The absolute values of death rates under one year of age related to the estimated population under one will necessarily exceed infant mortality rates, since the denominator of the latter exceeds that of the former; the trends of both rates should be parallel, however.

The relative completeness of returns for the population under one year of age in the censuses of 1880 and 1890 was a subject of contemporary controversy. The ages of children under one year of age were obtained by months in both censuses. However, Young (1901) points out that the change in the question relating to age from "age at last birthday" used in the census of 1880, to "age at nearest birthday" used in the census of 1890, intensified the effect of overstatement of age in the latter census. The deficiency in the census returns for children under one year of age in 1890 caused by this factor is estimated to be about 10 per cent.

The reliability of intercensal estimates of population under one year of age based on the returns of the census of 1890 is therefore open to question. It was necessary to assemble specific data relating to the nine cities included in this preliminary study for the purpose of determining the comparability of census enumeration for these areas, and, especially, the relative deficiency of the census of 1890.

•

It is of interest to observe the proportion of children under five who were under one year of age in these cities at each census from 1880 through 1930, as shown in Table 1. On the basis of a study of the census figures of European countries, Willcox (1933) states: "There is a strong presumption that more than one-fifth of the children under five at the time of any census were under one." The constancy of the occurrence of this proportion assumes small annual variation in the birth rate. For these nine cities as a group, the ratio of the population under one to the total population under five has been comparatively constant at 20 per cent or over at each census from 1880 through 1910. The decrease in the ratios of the majority of cities in 1920, and the further

TABLE 1

Percentage of total children under five years of age who were under one year of age at specified census date

CITY	1880 (*per cent*)	1890 (*per cent*)	1900 (*per cent*)	1910 (*per cent*)	1920 (*per cent*)	1930 (*per cent*)
Baltimore.....	22.3	20.8	21.5	19.7	21.4	18.3
Boston	21.7	22.0	21.7	21.3	19.5	18.8
Chicago	21.3	21.4	20.7	21.9	18.8	19.6
Hartford.....	20.2	22.3	22.9	21.1	20.3	19.6
New Haven	19.9	20.4	21.7	21.9	19.6	18.4
New Orleans ...	20.4	19.8	20.0	21.4	19.8	18.2
New York City (Former)....	22.2	22.5	22.2	22.4	19.6	18.6
Philadelphia....	21.6	22.2	21.4	21.5	19.9	18.6
Providence	21.7	21.7	21.5	21.8	20.9	18.4

decrease in 1930 is the anticipated effect of a period of declining birth rate (Whelpton, 1934).

It is to be noted that the ratios are not affected by the change in the age question in the census of 1890, since the returns for the population under five years of age were deficient to approximately the same degree as were those for the age group under one year of age.

A comparison of the percentage by which the number of registered births in the year preceding a census, exceeds or falls short of the census returns for the population under one in a given area, at the various censuses, affords a test of the relative completeness of the census returns for this age group. Table 2 shows these percentages for the cities included in this study, in so far as data on births were available, for each census from 1880 through 1930. Fig. 1 presents the number of live births and the estimated population under one year of age (actual in census years, estimated for intercensal periods), for each year from 1880 through 1930. The figures are plotted on a semi-logarithmic scale to permit a comparison of relative changes from census to census.

As the completeness of birth registration increases, the excess of births in the year preceding a census over the census returns for the population under one year of age should increase, if there is no variation in the completeness of the census returns. The figures in Table 2 show this increasing excess of births over the population under one as

TABLE 2

*Percentage by which the number of live births in the year preceding the specified census exceeds or falls short of the population under one year of age as enumerated in the census, in eight cities, 1880-1930**

CITY	PERCENTAGE EXCESS (+) OR DEFICIENCY (—)					
	1880 (*per cent*)	1890 (*per cent*)	1900 (*per cent*)	1910 (*per cent*)	1920 (*per cent*)	1930 (*per cent*)
Baltimore	— 5.1	— 2.0	—23.5	—11.1	+18.7	+26.3
Boston	+32.2	+48.3	+31.3	+30.7	+35.9	+52.8
Chicago	....	....	—25.7	—56.9	—17.3	+17.9
Hartford	+19.2	+17.4	+ 4.5	+11.8	+36.9	+60.2
New Haven	+29.7	+58.0	+14.5	+17.9	+24.8	+41.7
New York City (Former)	—15.2	+ 3.2	+ 2.0	+17.6	+26.9	+44.3
Philadelphia	— 1.8	+19.8	+ 2.5	+15.2	+18.2	+27.1
Providence	+ 9.3	+27.6	+20.9	+18.6	+18.3	+48.0

* The actual number of births in the year preceding the census was available for comparison with the population under one as enumerated on January 1, 1920, and April 1, 1930. The number of births in the year preceding the censuses of 1880, 1890, 1900 and 1910 was estimated by the following method: if the census date is June first (as in 1880, 1890 and 1900), the estimated number of live births occurring in the year ending May 31 equals 7/12 of the births in the calendar year preceding the year of the census plus 5/12 of the births in the calendar year in which the census falls. This method does not take into account seasonal variation in births, but permits a rough estimate to be made. A proportional adjustment was made in estimating the births in the year preceding April 15, 1910.

For Boston, Hartford, New Haven and Philadelphia the actual number of live births in 1880 was used, since the number of live births in 1879 was not available and the estimated births for the year ending June 1, 1880 could not be computed.

Figures not available for Chicago in 1880 and 1890.

New Orleans is not included since figures on live births were not available prior to 1927 in reports of the United States Bureau of the Census; and no local statistics on births were available.

enumerated in the census, in Hartford, New Haven, Philadelphia, Baltimore and the Former City of New York, at each census from 1900 through 1930. The ratio of births to the census returns for the population under one in Boston and Providence remains fairly constant through the censuses of 1900-1920, but rises, in both cities, in 1930.

THE RELATION BETWEEN THE NUMBER OF LIVE BIRTHS REPORTED AND THE ESTIMATED POPULATION UNDER ONE YEAR OF AGE

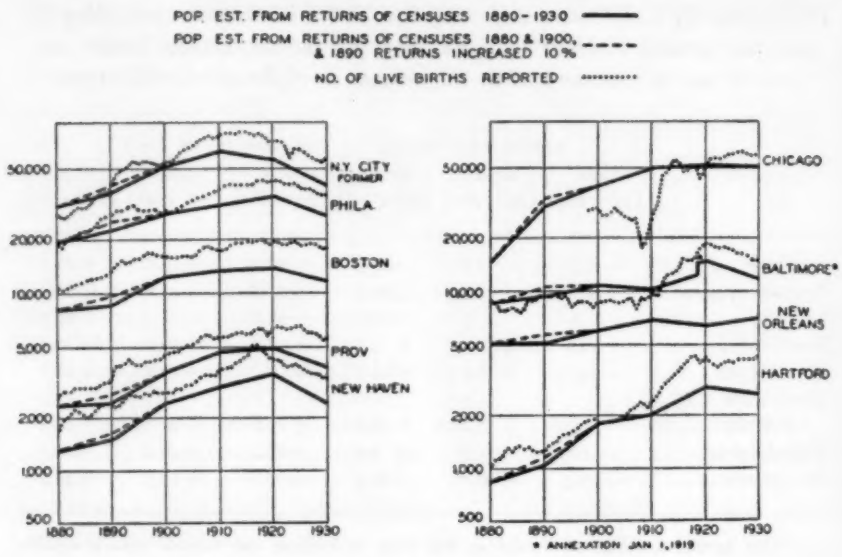

FIGURE 1

In a period of defective birth registration, the excess of births over the population under one year of age should be less than in a period of more complete birth registration. It will be conceded that birth registration in these eight cities was more defective in 1890 than in 1900. We should, then, expect to find the excess of births over the population under one, less in the census of 1890 than in the census of 1900, other things being equal. In the seven cities for which figures for both census years are available, we find, on the contrary, a greater excess of births in relation to population under one, in 1890 than in 1900. The excess is relatively small for New York City and Providence, but is marked in all other cities. The greater deficiency in birth registration in 1890 compared with 1900 cannot be denied. The abnormality of these ratios must be attributed to a relatively greater incompleteness in the census returns of the population under one year of age in 1890.

With the exception of the census of 1890, the completeness of the enumeration of the population under one appears to have varied little from census to census. An examination of the curves of the population under one in these cities, as shown in Fig. 1, confirms this conclusion.

In the period 1880-1910, there is a similarity in the rate of growth of the population under one year of age in the cities of New England and Middle Atlantic States: Boston, Providence, Hartford, New Haven, the Former City of New York, and Philadelphia. These cities experienced a somewhat similar rate of decline in the population under one year of age between 1920 and 1930. The rate of growth of the population under one year of age in Baltimore[4] and New Orleans has been lower than that for the northern cities. The population under one showed a decrease in comparison with the returns for the preceding census, in Baltimore in 1910, and in New Orleans, in 1920.

The unique characteristics of the curve of the population under one in Chicago reflect the rapid growth of this city.

With the exception of the returns for New Orleans in the census of 1920 (probably due to a deficiency in the enumeration of the negro population), the individual differences in the trends of the population under one year of age in these nine cities appear to harmonize with inherent differences in the movement of the total population, and cast no suspicion on the census returns. However, the curves of population under one year of age are brought into a more normal relation to the trend of births by assuming a deficiency in the census returns in 1890. This is brought out in Fig. 1.

Intercensal estimates of the population under one year of age based on the original census returns are therefore probably somewhat low for the decades 1880-1889, and 1890-1900, in all cities. In New Orleans, intercensal estimates of the population under one are probably low, also, in the decades 1910-1919 and 1920-1929. The estimates of population under one year of age in Hartford and New Haven in the period 1915-1919, and to some extent in the preceding five-year period, are low, due to the abnormal movement of population in these cities during the war.

The reliability of death rates of infants under one is also affected by the completeness with which deaths have been registered during this period. At the census of 1880, the death registration records of Massachusetts, New Jersey, the District of Columbia and a group of nineteen cities located in other States were considered complete enough to be used in determination of mortality rates in these areas for the census year. In his report on Vital Statistics for 1880, Billings states that the registration records of these areas "are based on a system of burial per-

[4] Part of the increase of population in 1920 was due to an annexation of territory on January 1, 1919.

mits, and are therefore probably very nearly accurate." Among the cities having satisfactory records in that year are listed the following, included in the present study: Baltimore, Chicago, New Orleans, New York, Philadelphia and Providence. Boston may be added to this list since Massachusetts was a death registration State. The legal requirement of a burial permit based on a death certificate in Connecticut dates from 1884. Death registration in Hartford and New Haven may therefore be considered to have been relatively complete from that date.

In the census of 1900,[5] the completeness of death registration in certain areas was subjected to a check by a comparison of the enumerators' returns of deaths with those recorded by State and municipal registrars. It was assumed that death registration in Boston, New York, Providence, Hartford and New Haven was complete, and the check was not made in these cities. In Baltimore, Chicago, New Orleans and Philadelphia, in which the completeness of death registration was in doubt, the check revealed that registered deaths formed over 90 per cent. of the total deaths (Chicago, 93.5 per cent; Baltimore, 95.0 per cent; New Orleans, 96.3 per cent; Philadelphia, 96.9 per cent).

Since death registration in these cities has been comparatively complete since 1880, increasing completeness of total death registration has probably been a factor of slight importance in its effect on the trend of the infant death rate.

GENERAL TREND OF INFANT MORTALITY IN NINE AMERICAN CITIES, 1880-1929

After this preliminary analysis, death rates under one year of age, related to the estimated population under one, were computed for our nine cities for each year of the period 1880-1929. These rates are shown in Table 3. The intercensal estimates of population were based on the original returns for the population under one in the Federal censuses of 1880 through 1930.

Because of the possible existence of a relatively greater deficiency in the census returns for 1890, due to the change in the age question, the intercensal estimates of population for the period 1880-1899 were recomputed using the original returns for the population under one in the censuses of 1880 and 1900, and the original returns of the census of

[5] Twelfth Census of the United States, 1900. Volume III. Vital Statistics. Part I. Analysis and Ratio Tables, pp. XIV-XXII.

TABLE 3

Mortality under one year of age in nine American cities 1880-1929
Deaths under one per 1,000 estimated population under one

Year	Baltimore*	Boston	Chicago	Hartford	New Haven	New Orleans	Former City of New York**	Philadelphia	Providence
1880	272.0	249.8	214.2	212.6	185.6	247.3	279.9	202.5	162.3
1881	272.9	246.4	269.2	279.7	198.9	243.7	305.1	209.9	175.8
1882	250.8	236.9	228.0	227.4	234.7	218.8	304.9	203.1	175.2
1883	265.2	263.5	198.9	258.5	251.8	245.2	263.0	202.2	175.0
1884	262.5	267.4	199.9	240.9	234.1	268.2	287.2	216.7	195.3
1885	242.1	255.7	178.1	192.1	217.7	275.2	272.4	228.8	155.8
1886	261.0	248.0	169.9	221.9	222.7	278.2	282.9	223.3	180.9
1887	261.0	269.4	175.3	199.2	236.2	263.2	285.3	239.6	185.2
1888	280.0	263.5	173.9	198.2	238.6	279.4	289.7	221.8	177.7
1889	272.1	270.4	174.6	197.1	217.8	241.6	288.2	231.3	202.3
1890	286.1	257.2	219.7	177.6	220.2	309.4	276.6	228.7	255.9
1891	271.2	277.5	257.4	204.9	193.3	273.2	290.5	232.4	221.0
1892	288.2	257.9	234.6	178.5	225.5	310.1	283.5	236.2	234.7
1893	262.3	254.9	246.5	196.3	219.7	288.2	266.3	232.1	241.5
1894	259.3	247.8	216.5	148.1	218.8	281.5	250.5	218.1	219.1
1895	267.6	241.9	195.8	169.9	215.3	308.4	252.0	214.4	213.4
1896	248.0	242.0	182.2	204.9	221.7	292.9	231.1	212.8	206.3
1897	236.6	215.9	156.4	173.9	152.4	234.7	209.9	175.2	192.6
1898	257.0	218.5	144.0	171.5	183.8	230.8	206.5	186.0	190.1
1899	226.8	198.1	143.3	184.6	135.7	255.9	180.5	165.5	194.0
1900	242.4	193.1	135.4	163.5	184.7	213.8	191.8	179.9	219.0
1901	236.0	181.6	124.7	122.9	152.6	169.5	175.4	162.7	190.2
1902	228.5	177.7	124.2	113.6	160.0	185.9	174.2	159.1	195.8
1903	204.0	169.6	125.4	129.4	155.0	170.8	160.6	155.6	220.8
1904	216.1	170.7	115.8	146.3	149.0	175.5	178.6	167.6	191.9
1905	233.3	167.7	131.4	149.3	157.3	176.5	178.4	165.9	161.4
1906	230.9	187.7	134.8	146.0	174.1	166.6	178.0	186.4	195.5
1907	232.8	177.2	144.6	148.3	139.7	195.0	177.2	174.8	187.6
1908	214.0	205.1	145.6	133.4	136.3	178.5	164.6	165.3	170.0
1909	216.5	157.6	132.2	118.3	141.4	156.5	158.9	149.9	161.9

TABLE 3 (Continued)

Year	Baltimore *	Boston	Chicago	Hartford	New Haven	New Orleans	Former City of New York **	Philadelphia	Providence
1910	208.6	165.7	139.3	139.7	136.1	155.3	158.6	158.8	174.5
1911	186.0	165.3	127.6	142.7	138.3	158.5	149.4	139.4	141.5
1912	187.5	160.4	135.0	176.1	137.6	115.8	142.7	124.0	136.6
1913	182.4	154.6	139.2	143.3	120.9	140.3	136.1	137.5	128.1
1914	172.9	146.7	137.7	154.2	129.1	133.7	131.7	146.3	145.5
1915	141.1	149.2	123.6	156.6	117.9	142.6	137.8	123.3	128.3
1916	150.4	149.6	137.0	154.2	134.1	118.3	126.5	122.8	135.2
1917	148.2	142.8	131.5	163.6	127.6	133.9	122.9	132.3	134.0
1918	184.0	166.7	130.5	185.4	128.0	147.4	122.4	153.0	161.2
1919	116.4	131.6	112.4	131.9	91.4	112.9	106.4	106.6	105.0
1920	133.3	143.3	111.0	144.2	106.3	121.1	114.4	109.6	119.6
1921	110.9	111.1	99.1	105.6	77.8	124.6	101.0	98.2	116.8
1922	112.8	129.2	95.3	115.7	90.5	125.6	99.6	99.2	104.2
1923	108.6	119.9	96.2	109.3	93.7	115.8	93.9	97.8	118.8
1924	109.4	114.2	89.4	88.4	95.7	126.3	93.0	96.8	116.8
1925	105.5	124.9	88.1	102.9	86.2	154.5	88.4	96.0	92.1
1926	105.2	126.0	79.4	110.5	71.1	123.7	88.7	98.5	98.7
1927	105.5	118.7	75.9	87.1	71.3	134.2	76.4	82.7	92.8
1928	105.1	119.8	74.9	75.3	78.5	114.7	92.2	90.1	94.1
1929	90.5	104.4	70.5	82.4	63.9	107.4	83.7	76.8	95.4

* Population estimates corrected for the annexation of January 1. 1919.
** Boroughs of Manhattan and Bronx.

1890 increased by 10 per cent. Death rates under one, related to these adjusted estimates of population under one, for the period 1880-1899, are shown in Table 4.

Intercensal estimates of population were made in all cases by the arithmetic method.[6]

[6] Recent evidence indicates little practical difference in the results of the use of the arithmetic and geometric methods in American population estimates. See Willcox, Walter F. Introduction to the Vital Statistics of the United States, 1900 to 1930. Page 12. United States Bureau of the Census. 1933.

The annual variations in these infant death rates were eliminated by the computation of five-year moving averages, using the corrected figures of Table 4 for the period, 1880-1899.

Finally, in order that the trend of the death rate under one per 1,000 estimated population under one might be compared with that of the

TABLE 4

Mortality under one year of age in nine American cities, 1880-1899
Deaths under one per 1,000 estimated population under one

(Population estimates adjusted by assumption of 10 per cent deficiency in census returns of population under one in 1890)

Year	Baltimore	Boston	Chicago	Hartford	New Haven	New Orleans	Former City of New York*	Philadelphia	Providence
1880	271.8	249.6	213.8	212.4	185.5	247.1	279.6	202.3	162.1
1881	269.6	243.6	263.9	275.9	196.6	241.1	301.2	207.3	173.8
1882	245.2	231.7	220.3	222.0	229.4	214.3	297.8	198.4	171.5
1883	256.6	255.1	189.8	249.5	243.7	237.8	254.2	195.5	169.6
1884	251.5	256.4	188.8	230.4	224.4	257.7	274.8	207.4	187.5
1885	229.8	242.8	166.7	181.8	206.7	261.9	258.2	216.9	148.0
1886	245.4	233.4	157.9	208.1	209.4	262.3	265.7	209.7	170.3
1887	243.2	251.2	161.8	185.3	220.2	245.9	265.6	223.1	172.8
1888	258.6	243.5	159.6	182.8	220.6	258.6	267.4	204.8	164.3
1889	249.3	247.7	159.4	180.5	199.8	221.6	263.8	211.8	185.4
1890	260.3	234.1	199.9	161.7	200.5	281.5	251.7	208.1	232.9
1891	249.3	255.7	237.0	189.1	178.4	251.2	267.6	213.8	203.7
1892	267.6	240.4	218.3	166.8	210.7	288.1	264.2	219.5	218.9
1893	246.0	240.1	231.9	185.6	207.7	270.5	250.9	218.0	227.8
1894	245.5	235.9	205.7	141.4	208.9	266.7	238.4	206.8	208.8
1895	255.8	232.4	187.8	163.7	207.6	295.1	242.2	205.3	205.3
1896	239.3	234.6	176.4	199.1	215.8	282.9	224.0	205.7	200.2
1897	230.5	211.1	152.7	170.2	149.5	228.8	205.3	170.9	188.5
1898	252.6	215.4	141.9	169.2	181.6	227.1	203.6	183.1	187.6
1899	225.0	196.7	142.3	183.2	135.0	254.0	179.3	164.2	192.8

* Boroughs of Manhattan and the Bronx.

TABLE 5

Mortality under one year of age in eight American cities, 1915-1930
Deaths under one year per 1,000 live births — five-year moving average — from the year of admission to the United States Birth Registration Area

Year	Baltimore	Boston	Chicago	Hartford *	New Haven	Former City of New York **	Philadelphia	Providence †
1917	....	103.8	....	105.0	84.4	92.9	106.4	....
1918	118.6	103.4	....	103.2	84.4	90.5	103.8	....
1919	111.6	97.8	....	98.4	79.0	86.4	98.4	....
1920	106.4	96.4	....	95.4	77.2	83.4	93.4	....
1921	93.8	89.8	....	87.6	74.0	82.0	84.6	....
1922	91.2	85.2	....	81.0	73.8	79.1	81.4	....
1923	86.4	82.0	....	75.6	69.6	74.7	78.6	77.2
1924	85.6	83.4	77.9	74.8	68.2	73.1	78.6	74.2
1925	83.4	80.2	73.7	72.0	64.0	69.7	74.8	71.8
1926	82.6	79.2	69.0	68.3	60.6	67.1	73.0	67.4
1927	80.2	78.2	65.7	69.4	55.6	65.9	70.4	64.8
1928	76.8	75.2	61.5	67.6	52.0	64.8	67.8	62.8

* Five-year moving averages, 1907-1916, prior to admission to U. S. Birth Registration Area, as follows:

1907 — 121.6	1910 — 114.8	1913 — 113.0	1916 — 107.6
1908 — 116.4	1911 — 113.6	1914 — 110.6	
1909 — 114.0	1912 — 114.0	1915 — 105.0	

** Boroughs of Manhattan and the Bronx.

† Dropped from the Birth Registration Area in 1919 and 1920.

infant mortality rate, five-year moving averages of the infant mortality rates of these cities were computed for the period 1917-1928. These rates are shown in Table 5. New Orleans is omitted, since Louisiana was not admitted to the United States Birth Registration Area until 1927.

Fig. 2 shows the five-year moving averages of mortality under one year of age related to estimated population under one plotted for each

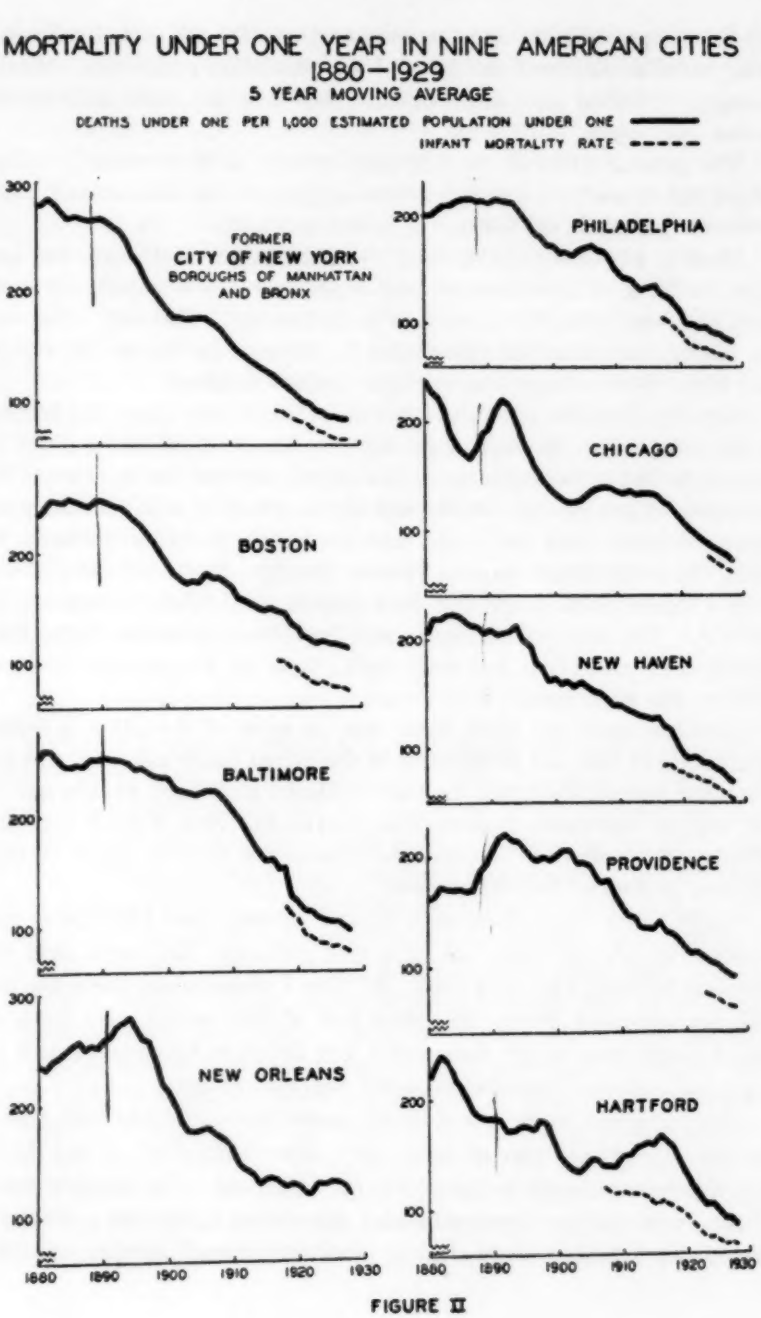
MORTALITY UNDER ONE YEAR IN NINE AMERICAN CITIES
1880—1929
5 YEAR MOVING AVERAGE
DEATHS UNDER ONE PER 1,000 ESTIMATED POPULATION UNDER ONE
INFANT MORTALITY RATE
FORMER
CITY OF NEW YORK
BOROUGHS OF MANHATTAN
AND BRONX
PHILADELPHIA
CHICAGO
BOSTON
NEW HAVEN
BALTIMORE
PROVIDENCE
NEW ORLEANS
HARTFORD
300
200
100
1880
1890
1900
1910
1920
1930

FIGURE II

city for the period 1880-1929, moving averages for the period 1880-1899 being based on adjusted estimates of the population under one. Moving averages of infant mortality rates are shown on the same scale for the period 1917-1928.

The general trend of the fifty-year curves for these cities is, on the whole, rather uniform and appears to suggest several distinct and widely prevalent phases in the history of infant mortality.

First of all, between 1880 and 1890, the infant death rate was on a high level (at or above about 200 deaths per 1,000 population under one) and was generally stationary or increasing. The only exceptions are Hartford, where the rate began to decrease in the middle eighties and New York, where a very slight decline occurred.

Secondly, between 1890 and 1900, there was a very sharp fall in seven of the nine cities. In Baltimore and Providence there was a slight decline only, but in the other cases this decade showed the most rapid fall registered at any period. At the end of this phase of rapid decline which began between 1890 and 1894 and continued for approximately ten years, the infant death rates of Boston, Chicago, Hartford, New Haven, New Orleans, New York and Philadelphia had fallen to between 125 and 175. The rates of Baltimore and Providence remained high; Baltimore's rates exceeding 200 until 1911, those of Providence remaining close to 200 until 1905.

Between 1900 and 1910, there was, in most of the cities, a definite retardation of the rate of decrease in the infant death rate. In Chicago, Hartford and Philadelphia the rate remained stationary at between 125 and 175; in Baltimore, Boston, New Haven and New York it decreased slightly. Only in New Orleans and Providence was the phase of rapid decrease prolonged into this decade.

Finally, since 1910 all the nine cities — except New Orleans — have shown a steady decrease, but at a rate generally less rapid than that manifest between 1890 and 1900. In New Orleans alone there has been little improvement during the latter part of this period. By 1929, the infant death rates of all these cities had fallen to between 64 and 107 per 1,000 estimated population under one year of age.

A comparison of the trend of the death rate under one with that of the infant mortality rate of these cities since 1917 discloses no significant differences except in the curves for Hartford. The absolute values of the death rate per 1,000 estimated population under one consistently exceed the infant mortality rates, since the annual number of births

normally exceeds the population under one surviving on a given date. However, the slope of the trend is not affected by the difference in the denominator unless the estimates of population under one year of age are particularly in error, as in the case of Hartford.

Thus, it appears from this preliminary study that the sharpest decline in the infant death rate which has been manifest in nine large American cities occurred in the last decade of the Nineteenth Century — before any general progress had been made in the pasteurization of milk or in organized clinic service. It is interesting to note that, according to the data cited by Newsholme (1935) this was not the case in England where the sharp decline in infant mortality set in only after 1900.

Following this sharp decrease there was a period of relative stability and about 1910 a second period of decline began. It is this second period of decline with which our subsequent study is concerned. The period from 1910 to date corresponds in time to the general pasteurization of milk supplies and to the development of the organized infant welfare clinic program. The results of a detailed study of the accomplishments of this last period in a large group of cities, in comparison with the actual development of these specific public health procedures, are presented in the following sections.

DATA USED IN THE PRESENT INVESTIGATION

A statistical evaluation of the relation between two factors is significant in so far as the basic data are exact. Thus, however important the effect of increased breast feeding on the decline of infant mortality may be, the statistical measurement of this relation is made impossible by the lack of quantitative information concerning the increase in breast feeding in a large population. Another important factor which falls in this category is the increase in knowledge of proper methods of infant care, due to instruction of mothers by private and clinic physicians, and by public health nurses. After extensive consideration, data as to clinic attendance of infants and pasteurization of milk seemed to offer the best promise of definite results in our study. With the organization and development of the modern well-baby clinic, record keeping has improved in accuracy and scope. The volume of attendance at infant welfare clinics therefore appeared to be a suitable factor for quantitative study. It seemed possible also to obtain exact figures on the proportion of the community milk supply which was pasteurized on a given date. Both pasteurization of milk and attendance of infants at well-baby clinics are

considered important phases of an adequate child health program, and have influenced, in theory, at least, the decline in infant mortality. The main purpose of the present investigation was the measurement of the extent to which these procedures have been associated with the decline in infant mortality in a group of cities.

In order to eliminate the influence of increasing completeness of death registration on the infant death rate, only cities located in the Death Registration Area, or designated as Death Registration Cities since 1900, have been included in this study. On this basis, 83 cities were available, their classification by population groups in 1900 being as follows: Thirty-six cities, population 100,000 or over; 38 cities, population between 50,000 and 100,000; 9 cities, population below 50,000 in 1900 but 100,000 or over in 1930.

The annual records of deaths of infants under one year of age in these cities were obtained from the annual reports of "Mortality Statistics", and "Birth, Stillbirth and Infant Mortality Statistics" published by the United States Bureau of the Census.[7] The population under one year of age was taken from reports on population of the Federal censuses of 1900, 1910, 1920 and 1930, the population for intercensal years being estimated by the arithmetic method.

The death rates of infants under one year of age were computed in relation to the estimated population under one year of age for each year of the period 1900-1929. Infant mortality rates could not be used for the entire period, since in the majority of these cities birth registration was incomplete until 1915. The deficiency of census returns for the population under one year of age is admitted, but is assumed, for reasons cited earlier in this report, to be approximately constant in the censuses since 1900.

The trend of the death rate under one year of age in each city was computed for the three decades 1900-1909, 1910-1919 and 1920-1929, the selection of the periods being made arbitrarily. In addition, the trend of the infant mortality rate was computed for cities which were in the United States Birth Registration Area throughout the decade 1920-1929.[8]

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[7] Figures on deaths under one year of age for the following cities in the years specified were not published by the United States Bureau of the Census, and were therefore obtained from the local health departments:

Charleston, 1925-1927 inclusive
Jacksonville, 1923
Memphis, 1916
Nashville, 1916
Saint Joseph, 1923-1929 inclusive
Savannah, 1923-1927 inclusive

[8] An exception has been made for the cities of New Jersey (and for Wilmington, Delaware), admitted to the United States Birth Registration Area in 1921; and for Providence, Rhode Island, temporarily excluded from the United States Death Registration Area in 1920. Infant mortality rates based on local figures were used for these cities for 1920.

Data on attendance at infant welfare clinics and the proportion of the milk supply pasteurized in each city in 1905, 1915 and 1925 were obtained by correspondence with health officers, milk inspectors, directors of visiting nurse associations and municipal nursing services. Most grateful acknowledgment is made of the courtesy of these various officials who have been more than generous in answering repeated requests for aid and in making elaborate searches of records to supply the data needed. The percentage of pasteurized milk was requested as of January first of the above years, clinic attendance, for the calendar year. Each city was requested to report the attendance of infants under one year of age at its infant welfare clinics, including those maintained by the Department of Health, and by private organizations. If figures on clinic attendance under one year of age were not available, the clinic attendance for infants under two was accepted as a substitute, the number of infants under one included in this total being estimated by the local authorities. Cities reporting clinic attendance for the age group under five, with no breakdown into the component age groups because of lack of records, were omitted from the correlations. Exceptions to the definitions of the data given above are noted in detail in connection with the presentation of the results of the correlations.

The statistical procedure was based on the assumption that the proportion of pasteurized milk, or volume of clinic attendance existing in the mid-year of a decade would influence the trend of infant mortality for the entire decade. The measurement of the correlation between the trends of pasteurization of milk or clinic attendance of infants for a given decade and the trend of infant mortality for the decade was not possible because of the secular trend exhibited by each of these variables. It was proposed, therefore, to measure the association between these variables by correlations set up as follows:

Trend of death rate under one year of age per 1000 estimated population under one in:	(1) *% milk supply pasteurized as of:*	(2) *Number of clinic visits of infants under one in calendar year:*
1900-1909 correlated with:	January 1, 1905	1905
1910-1919 correlated with:	January 1, 1915	1915
1920-1929 correlated with:	January 1, 1925	1925
Trend of infant mortality rate in:		
1920-1929 correlated with:	January 1, 1925	1925

It was assumed that the trend of the death rate under one in the periods selected was linear; the equation representing the trend is therefore in the form $y = a + bx$. The determination of the value of the constants a and b in this equation is made, according to the method of least squares, by the solution of the normal equations: $\Sigma Y = na + b\Sigma X$, and $\Sigma XY - a\Sigma X + b\Sigma X$.[8] If the origin is taken at the median value of the X's (years), then ΣX will equal zero, and the

first equation becomes: $\Sigma Y = na$. The value of the constant a is equal, therefore, to $\frac{\Sigma Y}{n}$; in other words, the constant a is the average of the observation values of Y, or the average of the actual mortality rates for the number of years represented by n. The sign of the constant a in the trend line equations is therefore positive. The constant b in this equation represents the slope of the trend line. If the sign of b is positive, the trend of the death rate under one is upward, i.e. increasing; if the sign of b is negative, the trend of the death rate under one is downward, i.e. decreasing.

In order to measure the relation between pasteurization, clinic attendance and the decline in infant mortality, the correlation between each of these variables and the constant b, or slope of the trend line of the death rate under one was determined. It was necessary also to compute the correlation coefficient for the specified variables with the constant a in the trend line equation, and also the coefficient for the constants a and b in order to determine the extent of the correlation between these constants.

The significance of the slope of each trend line was determined by computation of its standard error. The value of the constant b compared with its standard error was not significant for certain cities in each decade for which the trend of the death rate under one was determined. No exclusion of cities was made on this account, however.

Basic studies of correlation between trend of mortality under one year and percentage of the milk supply pasteurized

Replies were received from 65 of the 83 cities requested to report on the percentage of the milk supply pasteurized in 1905, 1915 and 1925. The completeness of the records of these cities varied at each period, 58 cities having information concerning the status of pasteurization in 1905, 59 in 1915, and 63 in 1925.[9]

[9] The following cities were available for the various correlations concerned:

Correlation of per cent of milk pasteurized with mortality rates of infants under one year of age (starred cities available in 1925 but not in 1915); Albany, Atlanta, Baltimore, Boston, Bridgeport, Buffalo, Cambridge, Camden, Charleston, Chicago, Cincinnati, Cleveland, Columbus, Dayton, Denver, Detroit, Duluth, Elizabeth, Erie, Evansville, Fall River, Grand Rapids, Harrisburg, Hartford, Hoboken*, Jacksonville, Kansas City, Mo., Los Angeles, Louisville*, Lowell, Manchester, Memphis, Milwaukee, Minneapolis, Nashville, New Bedford, New Haven, New York, Newark, Oakland, Philadelphia, Pittsburgh, Portland, Me., Portland, Ore., Providence, Reading, Richmond, Rochester, St. Louis, Salt Lake City, San Diego, San Francisco, Savannah, Somerville, Springfield, Mass.*, Syracuse, Trenton, Troy*, Utica, Washington, D. C., Waterbury, Worcester, Yonkers*.

Correlation of per cent of milk pasteurized with mortality rates for last eleven months of first year and with mortality for diarrhea and enteritis:

Preliminary correlations indicated a tendency for high values of the constant *a* to be associated with low values of the constant *b* (i. e. a marked downward slope). In other words, where the death-rate was high, its fall was rapid — a familiar phenomenon in all studies of vital statistics. This tendency was particularly marked in the decade 1910-1919. For this reason, the cities were classified in broad groups according to the value of the constant *a*, the coefficients of correlation being determined for each sub-group, as well as for the total number of cities reporting.

The correlation coefficients representing the relation between the trend of mortality under one year of age in the decades 1910-1919 and 1920-1929, and the percentage of the milk supply pasteurized in 1915 and 1925, respectively, are shown in Table 6. Because of the limited extent to which pasteurization was practiced in 1905, and the lack of uniformity in the methods then in use, the correlation between the percentage of the milk supply pasteurized in 1905 and the decline in infant mortality in the decade 1900-1909 was not determined.

In the interpretation of these correlation coefficients, certain facts concerning the slope (constant *b*) of the trend lines of the death rate under one in these cities should be noted. In the majority of cities, the slope of the death rate under one in the decades 1910-1919 and 1920-1929, and of the infant mortality rate in the decade 1920-1929, is negative, indicating a downward trend in mortality under one year of age. Values of the constant *b* which are high in an algebraic sense are to be interpreted therefore as slopes with a less marked downward tendency than those represented by low values of the constant *b*, a slope of —2, for example, being higher in value than a slope of —4, although the down-

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1915: Albany, Atlanta, Baltimore, Boston, Bridgeport, Buffalo, Cambridge, Chicago, Cincinnati, Cleveland, Columbus, Dayton, Denver, Detroit, Fall River, Grand Rapids, Kansas City, Mo., Los Angeles, Lowell, Memphis, Milwaukee, Minneapolis, Nashville, New Haven, New York City, Newark, Oakland, Philadelphia, Pittsburgh, Portland, Ore., Providence, Richmond, Rochester, San Francisco, St. Louis, Syracuse, Washington, D. C., Worcester.

1925: Albany, Baltimore, Boston, Bridgeport, Buffalo, Cambridge, Camden, Chicago, Cincinnati, Cleveland, Columbus, Dayton, Detroit, Fall River, Grand Rapids, Hartford, Los Angeles, Louisville, Lowell, Milwaukee, Minneapolis, New Bedford, New Haven, New York, Newark, Oakland, Philadelphia, Pittsburgh, Portland, Ore., Providence, Reading, Richmond, Rochester, Salt Lake City, San Francisco, Springfield, Mass., Syracuse, Trenton, Washington, D. C., Worcester, Yonkers.

TABLE 6

Correlation between trend of mortality under one year of age, 1910-1919 and 1920-1929, and percentage of milk supply pasteurized in 1915 and 1925

TREND OF DEATHS UNDER ONE YEAR OF AGE PER 1000 ESTIMATED POPULATION UNDER ONE — VARIABLES			CONSTANT *a*	NO. OF CITIES	CORRELATION COEFFICIENT	PROBABLE ERROR
% milk supply pasteurized as of Jan. 1, 1915	and	constant *b* (slope) of trend line 1910-1919	All values	58	.25	±.08
			Less than 132	30	.22	±.12
			132 and over	28	.24	±.12
% milk supply pasteurized as of Jan. 1, 1915	and	constant *a* of trend line 1910-1919	All values	58	—.27	±.08
			Less than 132	30	—.05	±.12
			132 and over	28	—.35	±.11
Constant *a*	and	constant *b* of trend line 1910-1919	All values	58	—.62	±.05
			Less than 132	30	—.40	±.10
			132 and over	28	—.67	±.07
% milk supply pasteurized as of Jan. 1, 1925	and	constant *b* (slope) of trend line 1920-1929	All values	62	.10	±.08
			Less than 100	31	—.01	±.12
			100 and over	31	.07	±.12
% milk supply pasteurized as of Jan. 1, 1925	and	constant *a* of trend line 1920-1929	All values	62	—.33	±.08
			Less than 100	31	.07	±.12
			100 and over	31	—.15	±.12
Constant *a*	and	constant *b* of trend line 1920-1929	All values	62	—.30	±.08
			Less than 100	31	—.23	±.11
			100 and over	31	—.29	±.11
TREND OF DEATHS UNDER ONE YEAR OF AGE PER 1000 LIVE BIRTHS						
% milk supply pasteurized as of Jan. 1, 1925	and	constant *b* (slope) of trend line 1920-1929	All values	56	.22	±.09
			Less than 80	39	.05	±.11
% milk supply pasteurized as of Jan. 1, 1925	and	constant *a* of trend line 1920-1929	All values	56	—.21	±.09
			Less than 80	39	—.04	±.11
Constant *a*	and	constant *b* of trend line 1920-1929	All values	56	—.47	±.07
			Less than 80	39	—.14	±.11

ward tendency of the latter is greater. Coefficients of correlation between two variables, x and y, one of which (y), is the constant b, are to be interpreted as follows:

(1) if the sign of the coefficient is positive, high values of the variable x show a tendency toward association with high (algebraic) values of y (constant b), i.e. a slope approaching the horizontal; conversely, low values of x are associated with low values of y (constant b), i.e. a marked downward slope.

(2) if the sign of the coefficient is negative, high values of the variable x show a tendency toward association with low (algebraic) values of y (constant b), i.e. a marked downward slope; conversely, low values of x are associated with high values of y (constant b), i.e. a slope approaching the horizontal.

The sign of the constant a in the trend line equations of these cities is always positive. Coefficients of correlation between two variables, x and y, one of which, (y) is the constant a, are therefore to be interpreted in the usual manner, a positive coefficient indicating a relation between high values of both variables, a negative coefficient, a relation between high values of x and low values of y, or, conversely, between low values of x and high values of y.

With one exception which is of slight importance because of the size of the coefficient (—.01), all coefficients of correlation between the percentage of the milk supply pasteurized and the constant b (slope) of the trend line, are positive. Thus the cities having a high percentage of pasteurized milk in the mid-year of a decade show a tendency toward a low decline in infant mortality within the same decade — exactly the reverse of what might have been expected theoretically. For deaths under one per 1000 estimated population this relationship is probably significant, statistically, for all cities in the decade 1910-1919 ($r = .25 \pm .08$, for 58 cities), but is not significant for either group of cities classified according to the value of constant a. In the decade 1920-1929, the correlations are not significant, whether pasteurization is correlated with the decline in the death rate under one per 1000 estimated population ($r = .10 \pm .08$ for 62 cities), or with the infant mortality rate ($r = .22 \pm .09$, for 56 cities).

The coefficients of correlation between the percentage of the milk supply pasteurized and constant a of the trend line equation are, with one exception, negative, indicating a tendency, of varying strength, for

"high-pasteurization" cities to experience a low average infant mortality for the decade. For deaths under one per 1000 estimated population, in the decade 1910-1919 the correlation is probably significant for all cities ($r = -.27 \pm .08$) and for the cities with high rates ($r = -.35 \pm .11$) but is not significant for the cities with low rates ($r = -.05 \pm .12$); in the second decade, the correlation is significant for all cities ($r = -.33 \pm .08$), but not for either subdivision. For deaths per 1000 live births in the second decade, no results are significant, although the correlation coefficient for all cities is $-.21 \pm .09$.

The really outstanding phenomenon is, obviously, the correlation between the constants *a* and *b* which was (for all cities) $-.62 \pm .05$ for deaths under one per 1000 population in the first decade, $-.30 \pm .08$ for deaths under one per 1000 population in the second decade and $-.47 \pm .07$ for deaths per 1000 live births in the second decade. Thus, the major factor at work is the tendency to show a high decline in mortality where initial rates were high and a low decline where they were low.

Because of this high degree of correlation between the constants *a* and *b*, it was important to determine the degree to which pasteurization and the decline in infant mortality are correlated, independent of the relation between the decline (constant *b*) and constant *a*. This relation is brought out by the partial correlation coefficients, shown in Table 7.

The elimination of the effect of the intercorrelation between constants *a* and *b*, with one exception, reduces the degree of correlation between the extent of pasteurization and the slope (constant *b*) of the trend line of mortality under one year of age which was observed in the zero-order coefficients. The reduction is not large enough, however, to cause a change of sign, i.e. to alter the direction of the association.

Two of these partial correlation coefficients suggest the probable true relation between pasteurization and the decline in infant mortality. The zero-order coefficient of correlation between the percentage of the milk supply pasteurized in 1915 and the slope (constant *b*) of the trend line, 1910-1919, for 28 cities in which the level of infant mortality for the decade was high (constant *a*, 132 and over), is $+ .24$. The coefficient of correlation between constants *a* and *b* of the trend line, 1910-1919, for these cities is $-.67$. When the effect of the latter high correlation is eliminated, pasteurization and the slope of the trend line still show a positive correlation, but the value of the coefficient, $+.002$, is so low as to be entirely without significance. A sharp contrast is offered by the effect of the partial correlation technic on the group of 30 cities having a relatively low average infant mortality (constant *a* less

TABLE 7

Partial correlation between the percentage of the milk supply pasteurized in 1915 and 1925, and the slope of the trend of infant mortality, 1910-1919, and 1920-1929, respectively, independent of the inter-relation of constants a and b

TREND OF DEATHS UNDER ONE YEAR OF AGE PER 1000 ESTIMATED POPULATION UNDER ONE		CONSTANT *a*	NO. OF CITIES	CORRELATION COEFFICIENT	PROBABLE ERROR
VARIABLES					
% milk supply pasteurized as of Jan. 1, 1915 and	constant *b* (slope) of trend line 1910-1919 independent of constant *a*	All values	58	.11	±.09
		Less than 132	30	.22	±.12
		132 and over	28	.002	±.13
% milk supply pasteurized as of Jan. 1, 1925 and	constant *b* (slope) of trend line 1920-1929, independent of constant *a*	All values	62	.003	±.09
		Less than 100	31	.003	±.12
		100 and over	31	.03	±.12
TREND OF DEATHS UNDER ONE YEAR OF AGE PER 1000 LIVE BIRTHS					
% milk supply pasteurized as of Jan. 1, 1925 and	constant *b* (slope) of trend line 1920-1929, independent of constant *a*	All values	56	.14	±.09
		Less than 80	39	.05	±.11

than 132) in 1910-1919. The zero-order correlation coefficient for this group of cities, measuring the relation between the extent of pasteurization and constant *b*, the slope of the trend line, is +.22. The relation between these two variables, independent of the effect of the constant *a*, is measured by the partial correlation coefficient, +.22. There is no tendency for the relation indicated by the zero-order coefficient to disappear, as there was in the group of cities in which the average level of

infant mortality was high. Thus, it seems possible that a positive, significant correlation between the extent of pasteurization and the decline in infant mortality would be revealed by a more extensive sample of cities having a high average level of infant mortality and an effective proportion of pasteurized milk. Such an ideal sample, however, cannot be obtained.

In general, then, this study brought out the following facts. Cities which had a high mean infant mortality for a given decade showed a rapid decline in infant mortality during that decade. This relationship was marked and significant. These cities with high (and rapidly decreasing) infant mortality, on the whole, tended to show a small amount of pasteurization. In other words, this group included an undue proportion of the more backward cities from a general sanitary standpoint.

Our failure to find any demonstrable influence of pasteurization upon the decline in infant mortality for the decade, 1910-1919, may perhaps be due to the fact that so few cities had an effective amount of pasteurization in 1915. Only 15 out of 58 cities reported 80 per cent or more of the milk pasteurized in 1915. In the decade 1920-29, when a larger number of cities had an effective amount of pasteurization (42 out of 62 cities with 80 per cent or more of the milk pasteurized) clinic service was also operating and apparently — as will be pointed out in a later section — exerting a greater influence upon the infant death rate. In any case, the results so far analyzed indicate that, with the data given, no effect of pasteurization can be demonstrated.

Supplementary studies of other relationships between pasteurization of milk and infant mortality[10]

In view of these negative results, obtained with mortality rates based on infant deaths for the whole of the first year, we though it might be worth while to explore other measures of infant health which might be more responsive to the effect of the pasteurization of milk. It seemed possible that a significant association between pasteurization of milk and the decline in infant mortality might be demonstrated be eliminating the infant deaths during the first month of life, which are chiefly determined by factors other than infant feeding. Accordingly, specific death rates for the last eleven months of the first year were computed for 38 cities for each year of the decade 1910-1919, the deaths being

[10] Our grateful thanks are hereby expressed to Dr. Henry Packer and to Dr. Grace Mooney for the carrying out of all these special supplementary computations.

TABLE 8

Correlation between trend of various measures of infant mortality, 1910-1919, and 1920-1929, and percentage of milk supply pasteurized in 1915 and 1925

PERIOD	VARIABLES	CONSTANT OF TREND LINE	NO. OF CITIES	CORRELATION COEFFICIENT	PROBABLE ERROR
	I. Per cent milk supply pasteurized correlated with trend of				
1910-1919	Deaths under one year of age*	*b*	58	.25	±.08
	Deaths, 2nd-12th month of first year	*b*	38	.06	±.11
	Deaths from diarrhea and enteritis under one	*b*	38	—.05	±.11
	Deaths under one year of age	*a*	58	—.27	±.08
	Deaths, 2nd-12th month of first year	*a*	38	—.06	±.11
	Deaths from diarrhea and enteritis under one	*a*	38	—.03	±.11
1920-1929	Deaths under one year of age**	*b*	56	.22	±.09
	Deaths, 2nd-12th month of first year	*b*	41	.20	±.10
	Deaths from diarrhea and enteritis under one	*b*	41	.18	±.10
	Deaths under one year of age	*a*	56	—.21	±.09
	Deaths, 2nd-12th month of first year	*a*	41	—.003	±.11
	Deaths from diarrhea and enteritis under one	*a*	41	—.14	±.10
	II. Constant *a* of trend line of:				
1910-1919	Deaths under one year of age*	*b*	58	—.62	±.05
	Deaths, 2nd-12th month of first year	*b*	38	—.58	±.07
	Deaths from diarrhea and enteritis under one	*b*	38	—.52	±.08
1920-1929	Deaths under one year of age**	*b*	56	—.47	±.07
	Deaths, 2nd-12th month of first year	*b*	41	—.61	±.07
	Deaths from diarrhea and enteritis under one	*b*	41	—.69	±.06

* Deaths per 1000 estimated population under one for all rates in the decade 1910-1919.

** Deaths per 1000 live births for all rates in the decade 1920-1929.

related to the estimated population under one year of age, and for 41 cities for the decade 1920-1929, during which the death rates were based on the number of live births. Finally, in the same manner, specific death rates for diarrhea and enteritis under one year of age were computed for these cities. The cities for which these specific death rates were computed represent the maximum number reporting on the extent of pasteurization in 1915 and 1925 for which figures on deaths specific for cause and month of the first year were available in published statistics of the United States Bureau of the Census for the corresponding decades.[11]

For both sets of death rates the trends for each decade[12] were computed and the correlation with the percentage of the milk supply pasteurized in the mid-year of the decade determined as in our earlier studies. The results are presented in Table 8, with pertinent data from Table 6 repeated for comparison.

While these specific measures of infant mortality show no significant correlations with the proportion of the milk supply pasteurized, it is of interest to note the reduction of the tendency toward association between a high proportion of pasteurization and low average mortality for the decade (with a correspondingly low rate of decline) which was observed in correlations with death rates for the entire first year. This reduction is marked in correlations with both constants *a* and *b* in the decade 1910-1919, and with constant *a* in the decade 1920-1929.

A striking and statistically significant correlation between the average mortality for the decade (constant *a*) and the slope of the trend line (constant *b*) is again revealed for mortality rates in the last eleven months of the first year, and for the death rate from diarrhea and enteritis under one year.

Analysis of annual changes in pasteurization and mortality in certain cities

All the analyses so far reported deal with comparisons between different cities where, obviously, many other factors come into play to complicate the situation. We, therefore, made a final effort to approach the problem in another way and to see whether, in a given

[11] See Footnote [9].

[12] The trends of these death rates for the cities of New Jersey, and for Providence, Rhode Island, were computed for the period 1921-1929; for Chicago, trends were computed for the period 1922-1929.

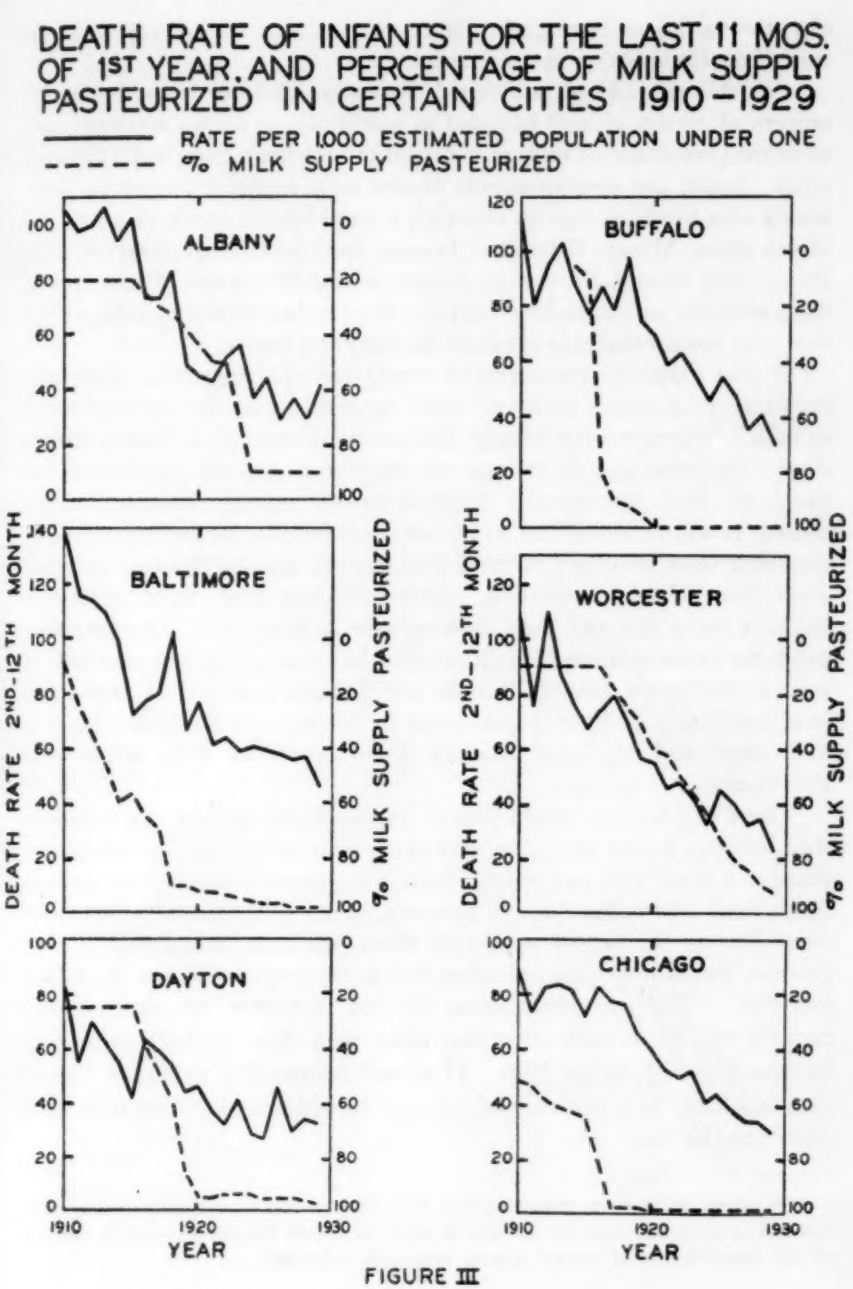
DEATH RATE OF INFANTS FOR THE LAST 11 MOS. OF 1ST YEAR, AND PERCENTAGE OF MILK SUPPLY PASTEURIZED IN CERTAIN CITIES 1910–1929
RATE PER 1,000 ESTIMATED POPULATION UNDER ONE
% MILK SUPPLY PASTEURIZED
ALBANY
BUFFALO
BALTIMORE
WORCESTER
DAYTON
CHICAGO
DEATH RATE 2ND-12TH MONTH
% MILK SUPPLY PASTEURIZED
1910
1920
1930
YEAR

FIGURE III

city, the variations in mortality from year to year might vary with the rate of development of pasteurization.

For this purpose we attempted, by correspondence with the health officers of certain cities[13] included in our study, to obtain accurate data as to the percentage of milk pasteurized in each year from 1910 through 1929. Again, our correspondents proved most cooperative and we were finally able to obtain figures covering a considerable series of years for eleven cities, Albany, Baltimore, Boston, Buffalo, Chicago, Dayton, Fall River, New Haven, Providence, Syracuse and Worcester. These annual data, with the corresponding mortality for the last eleven months of the first year are presented graphically in Figures 3 and 4.

A first glance at these graphs would perhaps suggest a direct and causative relationship between infant mortality and the pasteurization of milk. The curves for Albany, Baltimore, Boston, New Haven, Providence, Syracuse and Worcester all suggest a general parallelism between the two phenomena. A more careful survey, however, raises doubts. It will be noted that — in every instance — the general trend of the death rates follows a more or less straight line for the two decades, aside from chance deviations. The influenza year, 1918, generally shows a sharp rise and the following year, a sharp fall. On the other hand, the pasteurization of milk supplies had reached 90 per cent before 1918 in Baltimore, Boston, Buffalo and Chicago and did not attain this level until 1923 in New Haven, 1924 in Albany and Syracuse, 1929 in Worcester and had not reached it by 1929 in Fall River and Providence.

There can be little doubt that if one analyzed the absolute relationship between infant mortality and pasteurization of milk in successive years in a given city, one would obtain a statistically significant correlation. Such a procedure would, however, in our judgment be a fallacious one. During the period 1910-1929 there has been, in general, a progressive increase in pasteurization and a progressive decline in infant mortality. The two phenomena are not, however, on that account causally related to each other any more than they are both related to increased use of automobiles. If a real relationship exists, it should manifest itself in a tendency of the two variables to fluctuate with each other year by year.

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[13] A group of 41 cities reporting less than 80 per cent of the milk supply pasteurized in 1915 was selected for this inquiry, to which Boston was added because of the completeness of annual figures originally submitted.

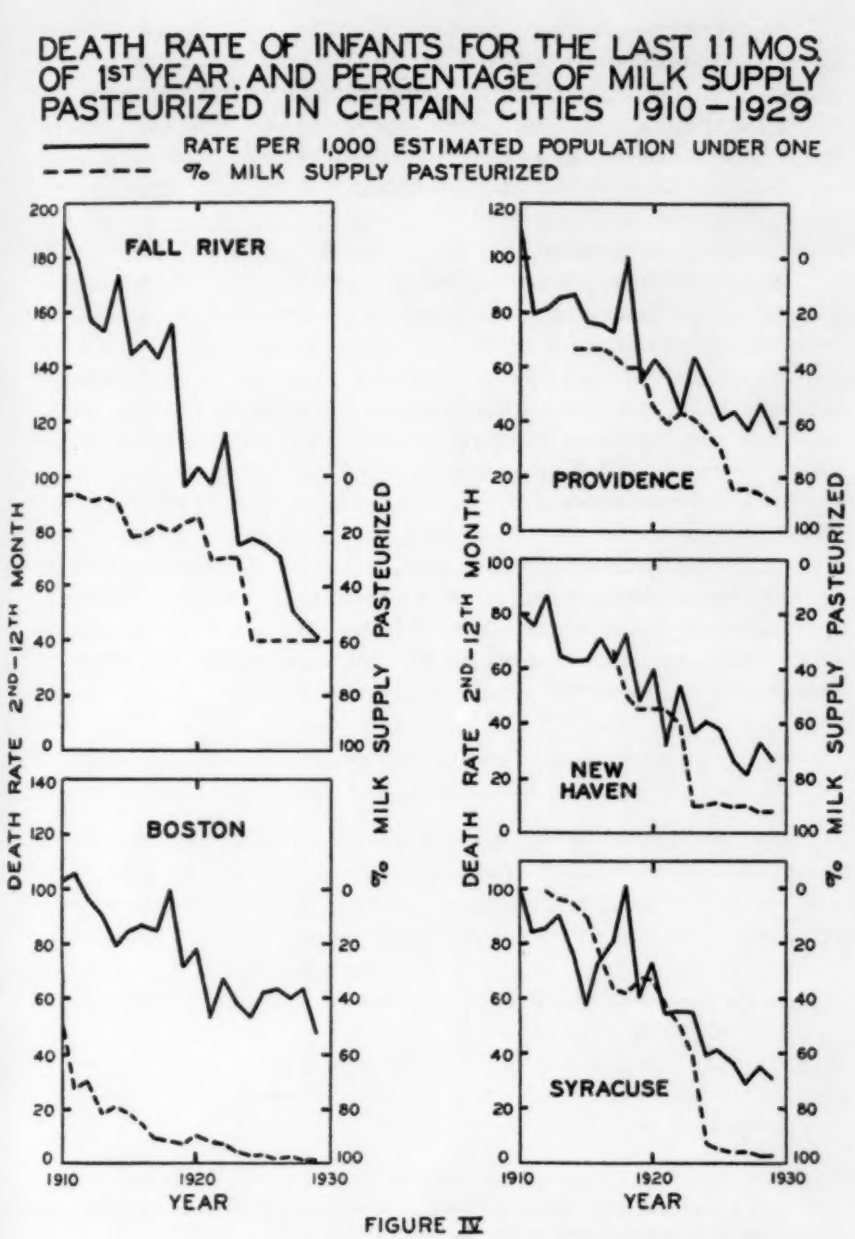
DEATH RATE OF INFANTS FOR THE LAST 11 MOS. OF 1ST YEAR, AND PERCENTAGE OF MILK SUPPLY PASTEURIZED IN CERTAIN CITIES 1910–1929
RATE PER 1,000 ESTIMATED POPULATION UNDER ONE
% MILK SUPPLY PASTEURIZED
FALL RIVER
BOSTON
PROVIDENCE
NEW HAVEN
SYRACUSE
DEATH RATE 2ND–12TH MONTH
% MILK SUPPLY PASTEURIZED
YEAR
1910
1920
1930

FIGURE IV

The crucial test seemed to us to be the relationship between annual increases or decreases in pasteurization and corresponding increases or decreases in infant mortality — compared in each instance with the figure for the preceding year. Such a procedure eliminates the general trend (which may be due to quite other factors) and makes it possible to determine whether the rate of change in the two variables ran generally parallel in given years.

We therefore computed for the available data annual changes in amount of pasteurization and in infant mortality (for the last eleven months of the first year). No significant correlations between these variables appeared for any city, — with a single exception. Providence showed a positive correlation of $+ 0.43 \pm 0.14$, that is the death rate fell most rapidly in years when increase of pasteurization was slight. The data for the whole group of 11 cities as a whole also showed a positive correlation of $+ 0.15 \pm 0.05$.

As a final test we thought it might be well to eliminate chance annual variations and — for both pasteurization and infant mortality — we computed three-year moving averages of annual differences and then worked out correlations between the figures thus obtained. This time, all results were negative. Specific death rates for diarrhea and enteritis under one year similarly analyzed had no more significance than the rates for all causes for the second to the twelfth month.

BASIC STUDIES OF CORRELATION BETWEEN TREND OF MORTALITY UNDER ONE AND VISITS TO INFANT WELFARE CLINICS

The next part of our program was an analysis of the relation between the visits of infants to well-baby clinics in 1905, 1915 and 1925 and the decline in infant mortality during the corresponding decades. It seemed to us that this was the most promising objective quantitative measure of the development of the organized movement for furthering the practice of breast-feeding and promoting a general comprehension of the principles of infant hygiene.

Information received from municipal health officers and directors of voluntary health and nursing agencies indicates that the well-baby clinic in its modern sense did not exist in 1905.[14]

[14] Milk stations were operated in Baltimore, Rochester and New York City in 1905. The Northwestern Medical School Dispensary of Chicago maintained a clinic for well and sick babies in that year. The Babies' Milk Fund and the Visiting Nurse Association of Cleveland maintained an infants' clinic in 1905,

The beginning of the infant welfare clinic movement took place a few years later, and the idea spread to an increasing number of cities during the decade 1910-1919. By 1915, however, well-baby clinics had not yet been established in approximately one-third of the 74 cities reporting in this study. The decade 1920-1929 saw the fullest development of the infant welfare clinic, and therefore promises the most significant results in a study of the effect of the movement on infant mortality.

A summary of the status of the clinic phase of infant welfare work in 1915 and 1925 in 74 cities answering the committee's questionnaire, is shown in the following table:

	Status of infant welfare clinics in 74 cities reporting as of	
	1915	*1925*
Infant welfare clinics maintained	47	71
Records available	32	68
Minimum age group used in records of attendance		
0-1 year	5	18
0-2 years	20	33
All other age groups	7	17
Records not available	15	3
No infant welfare clinics	27	3

Included among the agencies reporting attendance of infants from birth to two years of age are those in the following cities, the records of which vary somewhat from this classification: Duluth, 1915, 0-3 years; 1925, 0-2½ years; Dayton, 1915 and 1925, 6 weeks to 2 years; Minneapolis, 1925, 0-3 years; Cleveland, 1915 and 1925, 0-15 months.

The records of clinics in which figures on attendance were available only for the pre-school group as a whole were excluded from the present study, with the exception of a clinic in Portland, Oregon. This clinic was included, since its work supplemented that of another agency whose clinic records were classified for infants from birth to two years of age.

There were available for the final correlation analysis the clinic attendance of infant welfare clinics in 25 cities in 1915, and 51 cities in 1925, the original attendance records of which related to infants under one year of age, or from birth to two years of age. All records were then placed on a uniform age basis by obtaining local estimates[15] of the proportion of clinic visits of infants under two years

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which became the Babies' Dispensary and Hospital in the following year. The records of the activities of these precursors of the infant welfare clinic are not available. Starr Center, a voluntary agency in Philadelphia, organized an infant welfare clinic on April 1, 1905; this agency reported 180 clinic visits made by infants under one year of age in the nine months period.

[15] Estimates were made by the authors for the following cities: Indianapolis, Lowell, 1915; Oakland, 1925.

of age made by infants under one. The records of three cities[16] for which these local estimates were not received were excluded, since the data submitted did not permit a satisfactory estimate by the authors.

Six[17] of the cities having satisfactory records in 1925 were not in the United States Birth Registration Area throughout the decade 1920-1929. These cities were excluded in the final correlations since the trend of the infant mortality rate for the decade 1920-1929 could not be determined. They were excluded also in the correlation between clinic visits and the trend of the death rate under one per 1000 estimated population under one in order to make comparable the groups of cities used in both correlations.[18]

The correlation coefficients representing the relation between the clinic attendance of infants under one in 1915 and 1925, and the decline in infant mortality in the decades 1910-1919 and 1920-1929 respectively, are shown in Table 9.

The coefficient of correlation between clinic attendance of infants in 1915 and the decline (constant *b*, slope of the trend line) in the deaths of infants under one per 1000 estimated population under one in 1910-1919 is $-.05 \pm .13$. The relation between clinic attendance in 1915 and the average level of infant mortality (constant *a*) in 1910-1919 is also inverse, but again the correlation coefficient is not significant.

The results of the correlations with the trend of mortality under one in the decade 1920-1929 are of greater interest because the size of the sample permits a breakdown of the cities according to the value of the constant *a*. Clinic attendance in 1925 shows a negative correlation with the constant *b* (slope) of the trend lines of both the death rate under one (based on estimated population under one) and the infant mortality rate; that is, the cities having a large clinic attendance are those in which the decline in infant mortality is greatest. This relation holds to a greater degree for cities in which the average level of infant

[16] Hartford, Conn., Norfolk, Va., Paterson, N. J.

[17] Denver, Colo., New Orleans, La., Kansas City and St. Louis, Mo., Memphis and Nashville, Tenn.

[18] Cities used in this part of the study were as follows: Boston,* Bridgeport,* Cambridge,* Camden,* Chicago,* Cincinnati, Cleveland,* Dayton,* Detroit,* Duluth, Elizabeth, Erie, Grand Rapids,* Indianapolis,* Jersey City, Los Angeles,* Louisville,* Lowell,* Manchester, Milwaukee,* Minneapolis,* New Bedford,* New Haven,* New York,* Newark,* Oakland,* Omaha, Philadelphia,* Pittsburgh,* Portland, Me., Portland, Ore.,* St. Paul, Salt Lake City,* San Diego, San Francisco,* Somerville, Syracuse,* Toledo,* Trenton,* Waterbury, Worcester, Yonkers.*

Those cities starred were also used for computation of correlations with infant mortality rate in the last 11 months of the first year and with the death rate from diarrhea and enteritis.

mortality is low (i.e. constant *a* less than 80, in equations of the trend of the infant mortality rate) than for all cities reporting, in which the range of values of constant *a* is greater. In this group of 34 cities in which the constant *a* is less than 80, clinic attendance appears to be associated with the decline in infant mortality to a significant degree. ($r = -.38 \pm .10$.)

Partial correlation coefficients were computed in order to show the relation between clinic attendance and the decline in mortality under

TABLE 9

Correlation between trend of mortality under one year of age in 1910-1919 and 1920-1929, and clinic visits (actual or estimated) of infants under one in 1915 and 1925*

TREND OF DEATHS UNDER ONE YEAR OF AGE PER 1000 ESTIMATED POPULATION UNDER ONE		CONSTANT *a*	NO. OF CITIES	CORRELATION COEFFICIENT	PROBABLE ERROR
VARIABLES					
Clinic visits of infants under one* in 1915	and constant *b* (slope) of trend line 1910-1919	All values	25	—.05	±.13
Clinic visits of infants under one* in 1915	and constant *a* of trend line 1910-1919	All values	25	—.11	±.13
Constant *a*	and constant *b* of trend line 1910-1919	All values	25	—.52	±.10
Clinic visits of infants under one* in 1925	and constant *b* (slope) of trend line 1920-1929	All values	42	—.11	±.10
		Less than 100	31	—.24	±.11
Clinic visits of infants under one* in 1925	and constant *a* of trend line 1920-1929	All values	42	—.10	±.10
		Less than 100	31	—.03	±.12
Constant *a*	and constant *b* of trend line 1920-1929	All values	42	—.30	±.09
		Less than 100	31	—.37	±.10

(*Table 9 continued on next page*)

TREND OF DEATHS UNDER ONE YEAR OF AGE PER 1000 LIVE BIRTHS

Clinic visits of infants under one* in 1925	and	constant *b* (slope) of trend line 1920-1929	All values	42	—.20	±.10
			Less than 80	34	—.38	±.10
Clinic visits of infants under one* in 1925	and	constant *a* of trend line 1920-1929	All values	42	—.05	±.10
			Less than 80	34	.12	±.11
Constant *a*	and	constant *b* of trend line 1920-1929	All values	42	—.43	±.08
			Less than 80	34	—.20	±.11

* Per 1000 estimated population under one in specified year, for correlations with trend of death rate under one per 1000 estimated population under one; per 1000 live births, for correlations with trend of infant mortality rate.

one, independent of the intercorrelation between the decline (constant *b*) and the average level of infant mortality (constant *a*). These coefficients are shown in Table 10.

The elimination of the influence of the average level of infant mortality on the amount of decline in the rate for the decade, which is made possible by these partial (or net) correlation coefficients, indicates that the association between high ratios of clinical attendance and high rates of decline in infant mortality will hold true in a group of cities in which the average infant mortality rate is the same. Furthermore, the degree of this relationship is greater under the theoretical conditions, i.e. when the average infant mortality rate for the decade is the same for all cities, than under the actual conditions in which the value of the average rate is allowed to vary.

While, in general, the association between high ratios of clinic attendance and high rates of decline in infant mortality is intensified by these partial correlation coefficients, we find that varying degrees of this relationship prevail in the different groups of cities studied. Thus, the coefficient of correlation between clinic attendance in 1915 and the decline (constant *b*) in mortality under one in 1910-1919, independent of the effect of constant *a*, although of greater numerical value than the zero-order coefficient, is without significance in relation to its probable error. In the decade 1920-1929 the partial correlation coefficients for

TABLE 10

Partial correlation between clinic visits of infants under one, 1915 and 1925, and the slope of the trend of infant mortality, 1910-1919 and 1920-1929, respectively, independent of the inter-correlation of constants a and b

TREND OF DEATHS UNDER ONE YEAR OF AGE PER 1000 ESTIMATED POPULATION UNDER ONE		CONSTANT *a*	NO. OF CITIES	CORRELATION COEFFICIENT	PROBABLE ERROR
VARIABLES					
Clinic visits, infants under one, 1915	and Constant *b* (slope) of trend line, 1910-1919, independent of constant *a*	All values	25	—.13	±.13
Clinic visits, infants under one, 1925	and constant *b* (slope) of trend line, 1920-1929, independent of constant *a*	All values	42	—.14	±.10
		Less than 100	31	—.27	±.11
TREND OF DEATHS UNDER ONE PER 1000 LIVE BIRTHS					
Clinic visits, infants under one, 1925	and constant *b* (slope) of trend line, 1920-1929, independent of constant *a*	All values	42	—.25	±.10
		Less than 80	34	—.37	±.10

deaths under one per 1000 estimated population for all cities ($r = -.14 \pm .10$) and for cities having a value of less than 100 for constant *a* ($r = -.27 \pm .11$); and for deaths per 1000 live births, the coefficient for all cities ($r = -.25 \pm .10$), are suggestive although not statistically significant. The last coefficient presented in the table, for deaths per 1000 live births in a group of cities with a low average infant mortality rate for the decade ($r = -.37 \pm .10$) is distinctly significant.

SUPPLEMENTARY STUDIES OF OTHER RELATIONSHIPS BETWEEN CLINIC VISITS AND INFANT MORTALITY[19]

As in the case of pasteurization, we thought it might be well to supplement these primary studies by analysis of the correlation between clinic attendance of infants and specific infant mortality rates. Correlations for the decade 1910-1919 were not determined because of the small number of cities having adequate data on clinic attendance of infants in 1915, for which published figures on deaths under one year specific for cause and month of death were also available. For the decade 1920-1929, it was possible to compute the trends of the infant mortality rate during the last eleven months of the first year,[20] and of the infant death rate from diarrhea and enteritis, for 29 cities reporting adequate data on clinic attendance in 1925.[21]

Coefficients of correlation with clinic attendance were then calculated for the average level of each specific mortality rate for the decade (constant a), and for the slope of the trend (constant b). In addition, the correlation between clinic visits and the percentage uniform annual decrement (i.e. the ratio of constant b to constant $a \times 100$) of the trend of each of these specific infant mortality rates was determined. The results are presented in Table 11, with similar coefficients based on the crude infant mortality rate included for comparison.

It is of interest to note in Table 11 that all correlations of clinic attendance with both the slope of the trend line (constant b) and the percentage uniform annual decrement (ratio of constant b to constant a) of the various measures of infant mortality are negative, and therefore indicate an association between high ratios of clinic attendance and a high rate of decline of the mortality rate in question. Thus, correlations of clinic attendance with the specific infant mortality rates studied (deaths in the last eleven months of the first year, and deaths under one from diarrhea and enteritis, per 1000 live births) confirm the relationship previously observed in correlations with the crude infant mortality rate.

The correlations between clinic attendance and the slope (constant b) of the infant mortality rate for the last eleven months of the first year

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[19] Grateful acknowledgment is made to Dr. Grace Mooney for aid in carrying out these supplementary calculations.

[20] Trends of these specific infant mortality rates for 27 of these cities had been previously computed for use in the correlations with pasteurization.

[21] See Footnote 18.

TABLE 11

Correlation between trend of various measures of infant mortality, 1920-1929 and clinic visits (actual or estimated) of infants under one in 1925*

VARIABLES	CONSTANT OF TREND LINE	NO. OF CITIES	CORRELATION COEFFICIENT	PROBABLE ERROR
I. Clinic visits of infants correlated with specified trend constant of:				
Deaths under one year of age—all cities	*b*	42	—.20	±.10
Do.—Cities with constant *a* less than 80	*b*	34	—.38	±.10
Deaths, 2nd-12th month of first year	*b*	29	—.29	±.11
Deaths from diarrhea and enteritis under one	*b*	29	—.11	±.12
Deaths under one year of age—all cities	*a*	42	—.05	±.10
Do.—Cities with constant *a* less than 80	*a*	34	.12	±.11
Deaths, 2nd-12th month of first year	*a*	29	—.07	±.12
Deaths from diarrhea and enteritis under one	*a*	29	—.10	±.12
II. Constants *a* and *b* of trend line equation:				
Deaths under one year of age—all cities		42	—.43	±.08
Do.—Cities with constant *a* less than 80		34	—.20	±.11
Deaths, 2nd-12th month of first year		29	—.59	±.08
Deaths from diarrhea and enteritis under one		29	—.61	±.08
III. Clinic visits of infants correlated with percentage uniform annual decrement** of trend of:				
Deaths under one year of age—all cities		42	—.28	±.10
Do.—Cities with constant *a* less than 80		34	—.38	±.10
Deaths, 2nd-12th month of first year		29	—.48	±.10
Deaths from diarrhea and enteritis under one		29	—.29	±.11
IV. Constant *a* and percentage uniform annual decrement** of trend of:				
Deaths under one year of age—all cities		42	—.13	±.10
Do.—Cities with constant *a* less than 80		34	.02	±.12
Deaths, 2nd-12th month of first year		29	—.24	±.12
Deaths from diarrhea and enteritis under one		29	.19	±.12

* All rates per 1000 live births.

** Ratio of constant *b* to constant *a*, × 100.

($r = -.29 \pm .11$), and the death rate from diarrhea and enteritis under one ($r = -.11 \pm .12$) are lower than that for clinic attendance and the slope of the crude infant mortality rate in cities with a low average infant mortality for the decade ($r = -.38 \pm .10$); the last of these coefficients alone is statistically significant. When clinic attendance is correlated with the percentage uniform annual decrement, two significant coefficients are observed, that for the crude infant mortality rate, in cities with a low average rate for the decade ($r = -.38 \pm .10$), and the coefficient for the infant mortality rate in the last eleven months of the first year ($r = -.48 \pm .10$). The latter coefficient is notable because of its magnitude in relation to its probable error. The correlation between clinic attendance and the specific infant mortality rate for diarrhea and enteritis is again low, and without statistical significance.

The specific infant mortality rates show the high degree of association between the average level of mortality of the rate in question (constant a) and its rate of decline for the decade (constant b) previously noted for the death rate under one per 1000 estimated population, and the crude infant mortality rate. These specific rates show also an association varying in degree and direction, between constant a of the trend line equation and the percentage uniform annual decrement. It was important therefore to determine the correlation between clinic attendance of infants and the decline in these specific infant mortality rates, independent of constant a, i.e. the average observed rate for the decade. These partial correlation coefficients are presented in Table 12; the comparable coefficients for the crude infant mortality rate are also included.

In general, the results with the method of partial correlation point to an increase in the tendency toward the association of high ratios of clinic attendance of infants and a high rate of decline in the various measures of infant mortality studied. The correlation of clinic attendance with the infant death rate from diarrhea and enteritis, although higher than that observed in the zero-order correlations, remains comparatively low, and is without statistical significance. The most notable effect of the partial correlation technic is that observed with the slope (constant b) of the infant mortality rate in the last eleven months of the first year. The zero-order coefficient for this specific mortality rate is $-.29 \pm .11$; the partial correlation coefficient is $-.41 \pm .10$ — an increase which is sufficient to indicate a statistically significant correlation. Thus, the decline in both the crude infant mortality rate in the

TABLE 12

Partial correlation between clinic visits of infants under one, 1925, and the trend of various measures of infant mortality, 1920-1929*

VARIABLES	NO. OF CITIES	CORRELATION COEFFICIENT	PROBABLE ERROR
I. Clinic visits of infants correlated with the slope (constant *b*) of the specified mortality rate, independent of constant *a*:			
Deaths under one year of age—all cities	42	—.25	±.10
Do.—Cities with constant *a* less than 80	34	—.37	±.10
Deaths, 2nd-12th month of first year	29	—.41	±.10
Deaths from diarrhea and enteritis under one	29	—.21	±.12
II. Clinic visits of infants correlated with the percentage uniform annual decrement** of the specified mortality rate, independent of constant *a*:			
Deaths under one year of age—all cities	42	—.29	±.10
Do.—Cities with constant *a* less than 80	34	—.39	±.10
Deaths, 2nd-12th month of first year	29	—.51	±.09
Deaths from diarrhea and enteritis under one	29	—.28	±.12

* All rates per 1000 live births.
** Ratio of constant *b* to constant *a*, × 100.

group of cities with a low average rate, and in the infant mortality rate in the last eleven months of the first year varies directly and significantly in proportion to the ratio of clinic attendance of infants under one.

We also attempted to make an analysis of variations from year to year in individual cities for clinic visits as we had done for pasteurization. It proved very difficult to obtain reliable data as to clinic visits for individual years for any considerable period. Providence was the only city for which data could be obtained for as much as 13 years. For this city we did secure figures for all visits to clinics by children up to and including the pre-school age for 1917 to 1929 and computed the relationship between the increase or decrease in clinic visits for a given year as compared with the preceding year and the increase or decrease in mortality for the second to the twelfth month as compared with the preceding year. The correlation was not a significant one.

GENERAL CONCLUSIONS

From a general review of the data presented above, we may draw the following conclusions.

1. A study of infant mortality in certain large American cities, for which long-time records are available, indicates that the sharpest decline in infant mortality occurred in the period 1890 to 1905, before either the pasteurization of milk supplies or the development of an organized infant welfare clinic program had made appreciable headway.

2. After this phase of sharp decline the decrease in infant mortality slackened; and about 1910 a second period of steady decline set in which has continued unabated to the present day.

3. The decline in infant mortality which has taken place since 1910 has in general, run parallel with the enforcement of the practice of pasteurization and with the development of the organized infant welfare movement. It is not justifiable, however, to assume that the general coincidence in time of these phenomena represents a causal relationship, unless it can be shown that there has been a more intimate relation between the phenomena in question, as manifested by a correlation between their parallel variations in magnitude from city to city or from year to year.

4. So far as progress in the pasteurization of milk supplies is concerned, the data we have been able to obtain do not show any such relationship. All that our studies suggest, however, is that available statistical material is not adequate for the demonstration of the influence of pasteurization upon infant mortality. This does not mean that pasteurization is not actually an important factor in the control of such mortality. We have good general grounds for the belief that its importance in this regard is considerable, and its effect upon such diseases as typhoid fever and scarlet fever at higher age periods might very probably be susceptible of definite demonstration. The present study is merely an attempt to determine whether, from the data used, a statistical relationship between the date of initiation and the relative completeness of required pasteurization of milk, and changes in infant mortality rates could be shown. The failure to demonstrate such a relationship must not be taken as creating any substantial doubt as to the value of the practice of compulsory pasteurization of milk and milk products which is accepted by all sanitarians as an essential precaution.

5. On the other hand, even the somewhat scanty material available with regard to the development of infant welfare clinic service does make possible a definite statistical demonstration of the value of this type of service. It has been shown by this study that for the decade 1920-1929 there was a significant statistical relationship between the decline of the infant mortality rate in a group of American cities and the ratio of visits to infant welfare clinics by the infant population. This is somewhat surprising in view of the fact that attendance at infant welfare stations usually begins at an age when the most hazardous period of infancy has passed. It cannot be assumed that this relationship is governed by clinic service alone since clinic service is, for example, inevitably correlated with public health nursing service in the home. Clinic visits may, however, be taken as one objective measure of an organized community program for the control of infant mortality. It is of interest that at least this one factor in the infant welfare program has been justified by statistical analysis conducted with unusually rigorous precautions to avoid spurious correlations with general biological and social trends.

6. Perhaps the most important results of this study is a reemphasis of the need for more adequate statistical data with regard to public health procedures and their results. If infant deaths were more generally classified by cause and month of life, if definite statistical records were kept as to the age of the children when first attending infant welfare stations, and if data were available as to the amount of breast feeding actually practiced in a given community, far more significant results might be obtained.

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AN OBSERVATIONAL STUDY OF TWO CAPTIVE MOUNTAIN GORILLAS (GORILLA BERINGEI)

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GORILLAS have excited the imagination of men for several centuries, but only within the past few decades have scientists been concerned with bringing this highly specialized primate within the limits of relatively certain knowledge. Mentioned by Hanno in the fifth century and better described by Bartell in 1625, it was not until 1847 that this animal, largest of the anthropoid apes was definitely introduced to the scientific world by Savage and Wyman (13). Coincidently with the revolution of biological thought, a movement led by Lamarck, Darwin, Wallace and Huxley, there was a definite increase in the information about gorillas. This information supported the hypotheses held by scientists in the biological field. Careful descriptions by Sclater in 1877 (15), by Milne-Edwards in 1884 (10), and by Keith in 1896 (8) approximately established the true place of gorillas taxonomically. Scientists working with anatomical specimens recently acquired have answered many of the problems of classification (5). The lack of opportunity for the study of normal live gorillas has been an important factor in delaying the solutions to many problems of physiology, behavior and social relations of this significant anthropoid ape. To know an animal structurally is to know the animal

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in part and not the whole organism; to classify an animal taxonomically is to begin the complete study of it.

Few indeed have been the opportunities for studying normal specimens of gorillas of different ages and both sexes. This is readily learned by reading the literature as summarized by Yerkes and Yerkes (18). Falkenstein's (6) immature gorilla weighed thirty pounds when purchased and lived from June, 1876 until November, 1877, a total of sixteen months. Milne-Edwards (10) described the first living gorilla to be shown in France in 1884. The Breslau specimen, "Pussi", purchased in 1897, reached a weight of sixty six pounds by August, 1904 and died in October of the same year. As late as 1911, R. L. Garner (7) brought the first (possibly the second) gorilla to the United States. This animal weighed only twenty five pounds and lived thirteen days. Garner (7) was more fortunate with his second specimen, "Dinah", with which he arrived in New York August 21, 1914. This gorilla grew to weigh forty and one-half pounds and was three and one-half feet tall when it died July 31, 1915. Two animals were shown in Dublin, a young male that lived only a few weeks after its arrival and a female, "Empress", which lived for three years and four months in captivity. "John Daniel", the noted Cunningham specimen, lived in London from 1918 until 1921 when he was shipped to New York where he died. "Sultan", another Cunningham animal, lived in London from 1923 until 1927 (18). When it is realized that gorillas may grow to weigh four hundred pounds or more, it becomes evident that most specimens kept in captivity up until 1925 have been very immature, stunted or sickly individuals from which little could be learned about normal, typical gorillas, either about their anatomy or their behavior. Furthermore, most of the individuals have been isolated specimens from the study of which only inferences could be made about their social characteristics and relationships.

It is difficult to realize that not until 1925 was there available in this country a relatively normal, healthy, live gorilla which could be used for careful and valid scientific study. In that year, Mr. Ben Burbridge (2) brought "Congo" to his home near Jacksonville, Florida, where she was made accessible to Professor Robert M. Yerkes. Fortunately for science, Professor Yerkes had the wisdom to make the most of this valuable opportunity (17a, 17b, 17c) and there is available, therefore, relatively complete information about "Congo", a pre-adolescent female mountain gorilla.

At present there are available in the zoological gardens of the world at least fourteen specimens of gorillas. The locations of these specimens were given to me by Dr. W. Reid Blair: One female in the New York Zoological Park, two males (sex recently diagnosed by Michael Tomilin) in the Zoological Garden at Philadelphia, one female in the St. Louis Zoological Park, one male in the Chicago Zoological Park, one male owned by Mrs. William Lintz of Brooklyn, two specimens in the London Zoo, Regent's Park, one male in Paris, one female in Rome, and one at Frankfurt-am-Main. Consequently there are opportunities for complete and systematic studies of gorillas, especially if a few exchanges could be made.

Never, until recently, have two gorillas which were more suitable for scientific investigations been available in a situation eminently favorable for research purposes. It is doubtful whether there are in the world more desirable specimens than Ingagi and Mbongo, magificent mountain gorillas now living in the San Diego Zoological Garden. They are perfectly healthy and active and seemingly well adapted to life in captivity. The authorities of the Garden are very helpful and cooperative and the apes are accessible for study to qualified scientists.

These gorillas were captured by Martin Johnson in December, 1930 and delivered to the San Diego Zoological Garden on October 5, 1931. They were judged to be five and five and one-half years old when received, Ingagi being the older and Mbongo the younger. Mbongo lost his canine teeth in April, 1932, and then it was discovered that Ingagi had already shed his and re-cut all of his lower incisors and one of his upper incisors. According to these estimates and the time already spent in captivity, Ingagi should have been, when this study began, approximately eight and one-half years of age and Mbongo approximately eight years of age.

Ingagi was the larger of the two animals and weighed approximately two hundred and five pounds. He was well developed, strong and active. It was impossible to make measurements of him or his associate, Mbongo, since for more than a year the keepers had not gone into the cage with them. (The animals were weighed by putting a platform scale through a space below a door and getting the animals to sit on the scale.) Ingagi had a marked head crest and very prominent supra-orbital ridges. The crest and projecting jaws gave his head an oblong, massive appearance. His coat of hair was in good condition, very black but some-

what thinner than that of Mbongo. As far as could be detected, his teeth were perfect.

Mbongo weighed approximately one hundred and eighty five pounds. He was noticeably smaller and less well developed than Ingagi, although the two animals resembled each other closely. His head crest was not as large as that of Ingagi and his jaw was less prognathic. His face was more open and his eyes were not as heavily covered with supra-orbital ridges. His coat of hair was relatively short and thick and his teeth were sound and beautifully white, although apparently rather immature.

Table Showing Weights of Gorillas at Intervals from November, 16, 1933 to April 6, 1936

DATE	MBONGO	INGAGI
November 16, 1933	156	175
January 31, 1934	168	190
May 1, 1934	184	...
February 1, 1935	172	200
April 3, 1935	183	205
July 22, 1935	216	248
October 5, 1935	243	273
January 6, 1936	269	312
April 6, 1936	293	332

Shortly after the study began, I learned that there was some doubt as to the diagnosis of sex. It had been thought that the animals were a pair but there was uncertainty as to which was the male and which the female. The majority opinion held that Ingagi was the male. This conclusion seemed to have been based on a report that one of the superintendents had seen Ingagi with an erection. My lack of confidence in the previous diagnosis of sex was based on the highly similar physical proportions of the animals and the similarity in the shape of their heads, especially the head crests. I resolved to settle the question by a manual examination. For two weeks I conditioned the apes by feeding and grooming them, when they were accessible through the iron fence, so that I could put my hands on them. Eventually the gorillas assumed positions on the elevated platforms and floor which were favorable for

visual and manual examinations of their external genitalia. The following notes describe pertinent observations.

July 17, 1934. 9:15 A.M.: Ingagi assumed a position near the front fence which allowed me to see through the mass of rather long reddish hair that surrounds his penis and scrotum and to see these structures rather clearly. The penis with its sheath was not much larger than a lead pencil and not more that two and one-half inches in length. The scrotum was a semi-ovoid bulge of skin held closely to the body wall. Both the penis and the scrotum were surprisingly small as compared with the sex organs of chimpanzees.

At a later date when Ingagi was lying on the elevated platform in the corner of the cage, I was able to manipulate his genitalia for a few seconds.

July 23, 1934. 11:00 A.M.: As Mbongo lay on his corner perch with his thighs against the iron fence and his legs slightly separated, I had an excellent chance to see his genitalia. The slight bulge over his testes could be seen by reflected light. Palpation showed that the testes were ovoid in shape and approximately one and one-half inches in length and about three-quarters of an inch in diameter. It was possible to feel his penis in a mass of thick black hair. The organs were similar to those of Ingagi but somewhat smaller and more densely covered with hair.

The animals were found housed in quarters which made it possible to observe them very satisfactorily. Throughout most of the day they lived in the out-of-door cage which was forty feet by twenty feet by twenty feet in size. Within the cage there were many objects with which the animals could occupy themselves. There was a tree, a pool of water large enough for the animals to bathe in, a swinging rope, a chain with a hoop three feet in diameter attached to the end, a stump with considerable log, automobile tires, and several elevated corner platforms. Connected with the cage were two small sleeping rooms with elevated floors. Usually the gorillas were locked in one sleeping room during the night and allowed to range freely in the large open cage during the day.

PROCEDURES OF OBSERVATIONS

The procedures employed in this study were simple, direct observations. The animals could be observed throughout the day. For six days in the week from early in July until the middle of August, I

spent the mornings before their cage observing all possible behavior and recording it in writing and occasionally by means of photographs. Observations were sometimes made in the late afternoon. Once an experimental study was attempted. Various incentives were offered the gorillas in order to bring out certain qualities of behavior. However, is was found advisable during the study of social behavior to give the apes the maximum of freedom from interference and controls.

DESCRIPTIONS OF BEHAVIOR

Sexual Activity, Postures, and Locomotion

Previous to and throughout the summer of 1934 the gorillas showed almost complete lack of overt sexual activity. Not once in over two hundred hours of my observations did behavior occur that could have been interpreted as sexual. There was not a single instance of manipulation of the genitalia suggestive of auto-erotic stimulation. Neither of the animals showed the least interest in the genitalia of the other, even during grooming. In view of their seemingly normal health and growth one conclusion seems tenable: The young males were so immature even at approximately eight years of age that overt sexual behavior had not yet developed. Captivity and the lack of stimulation from females may, however, have been factors slightly delaying the onset of normal sexual activity.

June 22, 1936: Mrs. Benchley, Director of the Garden, wrote that Mbongo had not as yet shown signs of sexual excitement. Ingagi was said to have displayed mild sexual excitement and exhibited a slight tendency toward masturbation. Very infrequently he attempted to engage Mbongo in "sexual activity" but Mbongo would repulse him. Mrs. Benchley adds that their sex organs are as obscure as they were when I was at the Garden in 1934.

Gorillas show a variety of postures. During sleep and rest they most frequently lie on their sides, although they may lie on their backs and rarely on their bellies. When they assume the latter position they usually support the fore part of their bodies on their elbows (Plate I, Figs. 1, and 2). Much time is spent sitting both on their heels or flat on the supporting surfaces. Figures 2, 4, and 5 (Plate II) give some idea of the variety of postures common to these gorillas.

The gorillas at times show rather unusual postures. For example, Ingagi would climb to an elevated corner perch and perform the follow-

PLATE I. FIG. 1. RECLINING POSTURE, WEIGHT BEING RESTED ON ELBOWS AND LEGS DRAWN FORWARD. FIG. 2. RECLINING POSTURE, POSTERIOR VIEW, SHOWING LEGS EXTENDED BACKWARD. FIG. 3. RECLINING POSTURE. FIG. 4. GORILLA LYING ON A LARGE LOG AND STUMP AND HOLDING A ROPE. FIG. 5. GORILLA LYING ON HIS BACK AND PLAYING WITH HIS FEET. FIG. 6. THE FEET AND ONE HAND OF A GORILLA, SHOWING THE SMALL FINGER LOCKED OVER THE GREAT TOE.

PLATE II. FIG. 7. PHOTOGRAPH SHOWING THE GORILLAS AT PLAY AS INGAGI AVOIDS MBONGO BY GETTING BEHIND A TREE. FIG. 8. PHOTOGRAPH SHOWING MBONGO HOLDING THE IRON RING AND READY FOR A SWING. He is shown beating his chest. FIG. 9. AN INTERLUDE DURING PLAY. FIG. 10. PORTRAIT OF A GORILLA. FIGS. 11. and 12. A GORILLA INSPECTING HIS COAT. Photograph Number 12 shows the hair being manipulated and gives an excellent view of the foot.

Plate III. Fig. 13. A Typical Locomotor Posture From the Front. Fig. 14. A Typical Locomotor Posture From the Rear. Note the positions of the feet and hands which were photographed in motion. Fig. 15. Grooming Activity in Gorillas. Fig. 16. A Wrestling Bout. Fig. 17. Ingagi Climbing a Chain in Order to Get a Banana Suspended from the Top of the Cage. Fig. 18. Portrait of a Gorilla.

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ing postural stunt: He would stand with his feet wide apart, legs stiffened, body suspended from the hips and with his head hanging down lower than the level of his feet. When he was in this postion he would swing his arms, clap his hands together and sway his body to and fro. The latter behavior seemed directed toward Mbongo and appeared to be a type of *display*. On July 26, Ingagi suspended himself from a pendant ring and while hanging by his feet and one hand with his head almost touching the ground, he beat his chest with his free hand. In climbing, in scaling the overhead section of the cage and in resting, extreme postures are often assumed and maintained for short periods of time.

Characteristically the locomotion of gorillas is of a modified pronograde type. That is, the body is carried at an angle with the plane of support (Plates II and III, Figs. 9, 13, and 14). That the head and shoulders are carried considerably higher that the hips is due to the fact that the arms are much longer that the legs (Fig. 14). Only under extreme conditions do the animals evidence brachiating locomotion, however this was observed in Ingagi when he was attempting to get a banana placed on top of the cage, and in Mbongo when he was mounting into the tree. Infrequently and then only for short distances, do gorillas walk upright, or approximately so. When they do stand fairly erect, it is during play, chest beating or when they are carrying objects in their hands.

The arms and hands are quite as important during locomotion as are the legs and feet. From Figures 9, 13, and 14 (Plates II and III) the typical position of the hand during locomotion can be observed. The weight is placed on the knuckles and the first two joints of the fingers. These joints are flexed inward toward the palm of the hand. The dorsal surfaces of the flexed joints are covered with a tough, black, hairless, rubbery-like skin and flesh. (Plates II and III, Figs. 9 and 13). Rarely if ever do the thumbs touch the surface during locomotion. Note from the photographs that the dorsal surfaces of the hands are somewhat curved outward because the upper joints of the fingers are pressed outward by the weight placed upon them. The arms are held rigid and straight with a slight degree of supernation of the fore arm.

In general, the legs and feet appear to be weak and inadequate in proportion to the size of the gorillas. During locomotion, most of the weight is born by the external lateral surfaces of the feet. The surface of the heel comes into contact with the ground first and the great toe

plays an important rôle in the step. There is a V formed for an instant, as the foot is being lifted, between the large and the second toe. Typically the heel is raised first and then the foot is rolled somewhat outwardly and laterally; the great toe and the other toes in succession are raised from the ground.

Gorillas have several gaits which may be characterized as walking, trotting and cantering. Considerable variety is shown both in pattern and tempo. The speed of the movement is relatively slow, for rarely have I seen them cover the forty feet length of the cage in less than five seconds, running at the maximum speed observed. It would seem that gorillas can cover about eight feet per second or one hundred and sixty yards per minute; nevertheless in fright and anger, the speed of locomotion may be much greater.

I can say after adequate opportunity for observations, that the gorillas are slow, cautious climbers. It required Ingagi more than two minutes to climb the tree to a height of twenty feet and get a banana. They typically climb over the upper surfaces of branches in a pronograde fashion, but at times they stand relatively erect and walk out on a limb as they hold with their hands to a higher branch. Typically both hands and feet are used during climbing. Limbs are grasped between the thumb and the other fingers and between the great and other toes. That gorillas are somewhat reluctant to climb trees is indicated by the fact that they climb infrequently and that when one of the animals would seemingly escape the other during play, he would climb the tree and the other one would only infrequently follow him. These observations agree with those made in the wild, which indicate that gorillas are primarily terrestrial, ground-living animals. It is highly probable that their arboreal activity is restricted to occasional climbing during play, climbing for food and climbing for escape and protection.

It was interesting to observe the apes swinging by means of ropes from one perch to another. Repeatedly I have seen one of the animals carry the swinging rope by holding the end between his chin and chest and then, having gained his elevation in the tree, swing off in the direction of an elevated platform and land on it. Again, the animal would climb to the elevated platform and swing to a position in the tree. A similar type of behavior to this has been observed in howling (3) and spider monkeys (4) and this fact suggests possibilities for many new techniques for behavioral studies in primates.

Eating and Drinking

The gorillas ate large quantities of fruits and vegetables. During the entire period of observations, both animals had voracious appetites. In 1934 they were eating about fifteen pounds of food each day and that quantity has been increased to about twenty five pounds per day in 1936. They eat most of the seasonable fruits including oranges, apples, grapes, melons of all kinds, peaches, fresh corn, figs etc. In addition to this mixed diet of fruit and vegetables the gorillas are given milk and eggs which they seem to relish. They do not seem to eat meat, although I am not satisfied with the thoroughness of the tests.

With regard to food preferences, the following order seems to hold: Peaches, watermelon, grapes, bananas, oranges and corn. The animals' preferences vary with the amount and duration of the feeding of a particular food. When fed peaches and watermelon, they become very much excited even to the point of unusual vocalizations.

The animals eat rapidly and chew their food only slightly. Corn is stripped from the cob with their teeth cutting from end to end of the ear. The red fleshy part of watermelons is eaten first, and if the animals are hungry for this type of food, the entire rind is also eaten. "Chimp crackers" are often soaked in water before they are eaten and this soaking activity is carried over to other hard foods such as apples.

The gorillas drink large quantities of water. Just how much they drink was not determined, but certainly as much as two gallons per day. Their manner of drinking and its variations was interesting. Normally they put their mouths to the water and drank. When rushed or excited, as happened during periods of play, they would dip the water up in their hands, raise their hands over their heads and let the water stream down into their mouths. Again, they would take their food boxes or other containers and dip up water and drink it.

Their response to water was always positive for purpose of drinking, playing and bathing. In fact, it seems evident that constant access to a plentiful supply of water is one of the important factors in the success of the San Diego Zoological Gardens in keeping these animals in captivity healthy, contented and growing normally.

The behavioral attitude of the gorillas during excretion was most casual. Rarely if ever were special postures assumed during defecation. This act occurred during locomotion, play or while the animals were

lying down. It was different with urination, for usually the apes stopped, stood in a typical position for locomotion (Plate III, Fig. 13) and urinated.

Types of Gorilla Play

Play was decidedly the most prominent modality of activity. The regularity and vigor of the play activity was further indication of the health and vigor of the apes. Possibly also this play reflected beneficially on the health of the animals. For purposes of classification the types of gorilla play may be given as follows: *A*. Play with self such as manipulatory play, running, rolling or spinning and at times chest beating. *B*. Play with objects such as ropes, balls, sticks, water, tires, decorative objects and occasionally small live animals which become accessible. *C*. True social play such as wrestling, chasing, teasing etc. Generally speaking the characteristics of gorilla play are that it is vigorous, persistent and varied but lacking in that quality intermediate between play and pugnacity, otherwise known as play fighting.

Self play needs little description because of its simplicity. Under this heading would fall certain posturing which seemed to be enjoyed and was engaged in spontaneously. The animals would lie down at times and turn over and over or turn somersaults. Manipulation of the feet and toes was another sort of self play. Possibly the handling of genitalia as reported by Mrs. Benchley could be interpreted more correctly as play than as masturbation. Likewise the tactile exploration of teeth, mouth and ears was characterized by a play quality.

The following quotations from my notes describe several types of play and their inter-relations: July 15, 1934. 7:00 A.M. The apes carried straw from their sleeping quarters and played with it. Ingagi made a seat for himself, sat down and later, taking a handful of straw, he rubbed it up and down his belly. Mbongo began to tuck straw under his chin, adding a few straws at a time until a sizeable mat or apron was formed over his upper chest. By holding this straw with his chin, he carried it for several minutes and then let it fall. At other times the apes held bunches of straw between their hands and the cement floor and pushed it from one side of the cage to another.

Mbongo's act of putting straw under his chin might be interpreted as a kind of decorative act; at least Köhler (9) has made such an interpretation of a similar act in chimpanzees.

July 17, 1934. 10:00 A.M. Play with the swinging ropes and the ring and chain is one of the favorite types. Today Mbongo grasped the rope high above his head and while standing on one foot, set his body spinning, while he used his other foot as a motor and counterpoise. After spinning around and around for about fifteen times, he sat down.

This series of events was observed many times. After a large number of turns, the animals would sit down and close their eyes. From this one might infer that the animals were slightly dizzy; although I have seen only very slight evidence for nystagmus.

July 20, 1934. Ingagi played for many minutes in the pool of water. At first he dipped the water up in one hand and let it run into the other. Later he slapped most of the water from the pool. Then he took water into his mouth and let it run out again. Water is one of the apes' most preferred playthings.

Running water from a hose fascinated them. Whenever possible, they would come to the end of the hose and open their mouths for the stream to pour in. The animals competed for this stream almost as they would compete for food.

A type of skating or sliding play was quite common. After the floor had been flushed or after the apes dashed water on it from the pool, skating almost invariably occurred. Instead of skating with their legs and feet, they skated with their arms and hands. With their arms stiffened and held forward at an angle from their shoulders and with their knuckles in contact with the cement, while running with their feet, they would slide their hands from one end of the cage to the other and back again until they became fatigued. Typically this was done at a trot or rapid run.

August 13, 1934. I put an inflated rubber ball twelve inches in diameter into their cage. Immediately Ingagi and Mbongo began to compete for the plaything. Ingagi succeeded in taking it away from Mbongo, thus showing dominance for the possession of a play object. While Ingagi was playing roughly with the bladder, it burst, and although he held the deflated rubber in his hands, he seemed puzzled and looked around for the previously air-filled ball. Later the gorillas pulled the deflated bladder into pieces, each taking a part.

The social type of play was most frequently engaged in by the gorillas. The following notes describe several types of social play: July 14, 1934. 11:00 A.M. Wrestling gave way to a kind of chasing play. The chasing seemed to arise out of the decreased motiva-

tion of Ingagi for play and his attempts to escape encounters with Mbongo. Ingagi fled while Mbongo followed him to all parts of the large cage, over the ropes, up the pendant ring, across the fallen stump, up the dead tree and over most of the surface of the iron cage netting. At times the behavior was definitely regular and circuitous. During such times, definite patterns of activity were exhibited repeatedly. For example, each animal in turn approached the fallen stump, put his hands on it and slid over on his belly. In this play as during wrestling, Mbongo was the aggressor and was superior.

Chasing play of a simple form was usually intermixed with wrestling which was far more complex. At times the animals would wrestle intermittantly for several hours, but periods of actual contact and vigorous struggle rarely lasted more than a few minutes, on the average not more than fifteen or twenty seconds. The following excerpt from my notes gives some idea of the characteristics of these struggles: July 14, 1934. 7:00 A.M. The gorillas had been separated for the night and upon being released, began wrestling immediately. In the approach to the clinch, the apes stood almost erect, each put his long prognathic jaw over the shoulder of the other one and each clasped its arms around the other one in a strong embrace. A struggle followed which lasted approximately twenty seconds. After a brief pause, seemingly for rest, the struggle and tussle were repeated, and thus periodically rest followed struggle, and interspersed with these were occasions when Mbongo chased Ingagi over the floor of the cage.

Mbongo was the aggressor. It was he who approached Ingagi and initiated the play, whereas Ingagi either ran away or stood his ground and reciprocated in the wrestling competition. Always Ingagi was very observant of Mbongo as though expecting him to attack instantaneously.

On the same day at 9:15, after a period of inactivity, the gorillas became actively engaged in wrestling play. Mbongo began the contest as usual. They clutched each other as previously described but in addition, each used his mouth with which to hold and to annoy his opponent. Wrestling lasted continuously for about one minute, was interrupted for thirty seconds and then resumed. While the animals separated temporarily, they would beat their chests. This chest beating occurred typically just prior to an attack and seemed to signify a *challenge* for an engagement. While wrestling, each animal seemed to strive for that position of advantage which would allow him to bite at the nape of the other animal's neck. This seemed one of the main objectives toward

which the behavior was directed. Wrestling lasted for fifteen minutes, was interrupted for a short period of rest and was then continued with renewed vigor.

July 18, 1934. 4.00 P.M. The apes were engaged in vigorous play consisting of chasing, striking and wrestling. For several minutes Mbongo ran after Ingagi as he went around and around the cage and then circled the tree. Suddenly Ingagi stopped, beat his chest and a typical wrestling match occurred. The clinch was broken and the animals became separated by the tree trunk and Mbongo dodged from Ingagi then by shifting from one side of the tree to the other. Mbongo finally dashed for Ingagi and they were off for another period of chasing which later ended in a wrestling encounter. Ingagi carried the swinging rope to one of the corner perches by carrying the end under his chin as he climbed. When Mbongo approached him by climbing the iron netting, he swung off the platform while at the same time holding on to the rope. Later he swung by Mbongo and gave him a vigorous kick as he passed him.

July 24, 1934. The apes have been wrestling sporadically for more than half an hour. Mbongo has been holding Ingagi by looping one arm over his shoulder and the other under his thighs. Sometimes wrist locks are made. The animals have also exchanged playful blows. Always the open mouth has played an important rôle in the wrestling bouts. Coincident with the clinch, mild biting and grunting were noted.

Any attempted verbal description of the majestic wrestling play of gorillas does the activity an injustice. Powerful and massive yet agile, the gorillas play dramatically and vigorously.

Chest beating which has been elaborately described in the literature on gorillas was studied advantageously. Its pattern, the situations in which it occurred and its behavioral significance were closely observed. The pattern of chest beating was a rather rapid, alternating slapping of the opened hands against the upper chest region. It occurred exactly as described by Professor Yerkes in his valuable monographs on "Congo", (17a, 17b, 17c). Logs, other objects and floors were beaten in a like manner during situations provocative of play activity. Without exception, as far as my observations go, when the chest or objects were beaten, with the characteristic chest beating rhythm, the apes were in a playful, contented mood. I seriously doubt that this type of behavior would occur when the animals are greatly disturbed or angry; although I never observed them so motivated.

Chest beating has communicative significance i.e., it is oriented from one animal toward the other. The many instances of chest beating which I observed have led me to place two significant interpretations on this act: First, the behavior seems to be a form of playful *challenge*. (See Plate II, Fig. 8.) Mbongo would beat his chest and then dash after Ingagi to engage him in a wrestling match. Again, Ingagi would stop running from Mbongo, stand almost erect, beat his chest and meet his opponent in a clinch. Second, chest beating seems to be a form of *display* behavior. Ingagi would climb to a high perch in the tree and while standing poised, beat his chest. While assuming some unusual posture he would beat his chest. At times he would perform some feat, as on the swinging rope, ring or elevated platform, and immediately afterwards beat his chest. Chest beating also occurred when he seemed particularly anxious to attract the attention of a person to whom he was attached. These interpretations of challenge and display give meaning to an interesting and unique feature of gorilla behavior.

Grooming and Care of Wounds

Grooming is a conspicuous modality of behavior in sub-human primates. Yerkes (19) and Zuckerman (20) have given interesting descriptions and significant interpretations of this mutually beneficial social behavior. Limited previous observations of grooming in gorillas seemed to indicate that it occurs rarely and is atypical in pattern when compared with grooming as found in chimpanzees. Certainly it does not occur as frequently in gorillas as in chimpanzees but it is by no means rare. I suggest that it occurs about as frequently in gorillas as in spider monkeys (4). The pattern of the act, as far as I could observe, is almost identical with that to be observed in the chimpanzee, but it is carried out at a much slower tempo and the mouth is not used as much.

It seems worth while to distinguish two types of grooming; self grooming and social grooming. Figures 11 and 12 (Plate II) give an excellent conception of self grooming. This behavior is shown daily, sometimes hourly, and certainly serves to keep the coat of hair clean of foreign matter. The manipulation of self grooming is similar to that of social grooming. The following is a detailed account of social grooming: July 15, 1934. 9:00 A.M. Mbongo lay first on his back, turned to his right side and then on his belly. Ingagi approached him gently and cautiously and began the same kind of grooming behavior

that I have observed many times in other kinds of monkeys and apes. He sat in contact with Mbongo as he parted the hairs of his coat and fingered over his skin much after the manner of chimpanzees. (Figure 15, Plate III shows Mbongo grooming Ingagi). Although both hands were used, the right hand was the predominant one. (Both animals were right handed). The hair was parted systematically and the particles and scabs were removed by the finger and thumb of the right hand. Once Ingagi parted the hair with his left hand, held it parted with his chin and protruding lower lip, and performed finer movements of prehension with his right and left fore-fingers. Ingagi turned Mbongo over on his back and continued to groom his abdomen and the lower parts of his chest. During grooming, Ingagi rested on his chest and forearms. Periodically, Ingagi would stop grooming Mbongo and then groom through his own coat. During the morning several periods of grooming were alternated with periods of wrestling. Many times afterwards I noted that when grooming occurred on a given day there was a high probability that it would occur repeatedly on that same day.

It is important to note that Ingagi usually took the active part during grooming, (the instance when the photograph, Figure 15, was taken being an exception) and Mbongo took the passive, receptive part.

As Professor Yerkes has pointed out, grooming is a form of adult primate behavior most nearly approaching mutually beneficial cooperation. At San Diego one finds an ideal situation for the occurrence of this form of behavior, for the two gorillas were strongly attached to each other and they were isolated from other members of their species.

At times the apes would get small cuts and bruises of varying degrees of seriousness. To these they gave meticulous care: On July 19 Mbongo seemingly hurt his right hand during play. For several minutes he carried his hand in his mouth and later he put it into the water basin and kept it there for several seconds. Later he held his bruised hand near the water basin and dipped water on it with his other hand. During the days of August 8 and 9, Mbongo repeatedly dressed a small wound on the top of his left foot. He pulled the hairs from the wounded area and would at times put his lips to the broken skin. During the next week Mbongo got a slight cut on his left shoulder and Ingagi was repeatedly treating the wound for Mbongo. Whether or not these methods of dressing aid healing is questionable. It is certain that healing is not seriously retarded by them, for small cuts and bruises heal very rapidly, usually within two or three days.

Vocalizations and Gestures

Having previously studied several genera of New World monkeys (3, 4) and chimpanzees, I was surprised to find a smaller range of vocalizations in the gorilla. Since vocalizations are very closely related to the higher mental processes and to emotional expression, such sounds should be indicative of the qualities of these processes. Mbongo and Ingagi expressed themselves vocally mainly by a series of grunts with variations. These sounds were usually of a low pitch and uttered in series. Typically the grunts were of a similar pitch, volume and intensity; however when an animal was excited, his low pitched grunt of considerable intensity was gradually transmuted into one of considerably higher pitch. Variations in meaning, *judged from changes in the behavior of the associated animal,* could be made by changing the tempo with which the grunts were given. With suitable recording apparatus, an excellent study could be made of the vocalizations of these apes. In the mean-time, crude verbal descriptions of their vocalizations seem futile. Suffice it to say that vocalizations play an important rôle in coordinating the social behavior of the gorillas.

Gestures, both fine and gross, contribute importantly in the social relations of the animals. The face of a gorilla is very expressive. The expression of the eyes is changed by raising and lowering the eyebrows and by the degree to which the eyes are opened. The lips are the most expressive part of the face as can be learned from a close study of Figures 11, 17 and 18 (Plates II and III). The protruding lips and the degree to which the mouth is opened indicate in a general way the mood or emotional set for action. There is no doubt but that these finer changes of facial expression become conditioned stimuli for the associated animal and serve to indicate incipient gross behavior. There are other gross gestures that have social significance. As has been shown, chest beating is of this type and is very important. Stamping on the ground and certain rhythms of walking are other gestures which have special but as yet unknown meaning for the gorilla. When an animal is caged alone or when locked in the sleeping quarters temporarily, he may stamp and pound the floor. This behavior is seemingly indicative of extreme annoyance and frustration. Thus when the behavioral patterns which have communicative significance in social relations are considered, it would seem that gestures are equally as important to gorillas as vocalizations. Both subjects need further study.

There seemed to be considerable imitator-imitatee relationships between the two gorillas when their moods and behavior were properly synchronized. However, the problem is raised of what is meant by imitated behavior. Acts which are merely initiated by the activity of another animal are not acts of imitation. The following examples are those in which the behavior of one animal set off similar behavior in another animal, although the behavior stimulated is already a part of the action system of the second animal. This behavior may be called *copying* as contrasted with the true imitation. One of the gorillas would begin to dash water from the pool and the other one would follow suit. It is reported that the animals would copy a rhythm of locomotion as set by their keeper, but I was unable to verify this. Furthermore, simple forms of behavior such as playing with objects, swinging ropes or rings are copied from one animal by another. If Mbongo had the opportunity to let water run from a hose into his mouth and Ingagi saw him, immediately Ingagi would chase Mbongo away and take the water in his own mouth. In this instance there is a striving for a common incentive which requires similar behavior patterns. When the behavior of one animal stimulates similar behavior in another, there is shown an interesting and important type of social behavior that deserves further study, be it imitation or a more simple form of activity.

Dominance and Cooperation

The subject of dominance in animals has occupied the attention of psycho-biologists for a number of years and promises to be important for some time. Initial observations indicated clearly that Ingagi was the more dominant animal in feeding situations. If both animals were fed in the same room, Ingagi hogged the food. When Mbongo was fed first and Ingagi approached, Mbongo would run away carrying as much of the food as possible. Even when they were fed in separate rooms, Ingagi would run from one to the other, taking his choice from the food supply. Only once did I see Ingagi take food from Mbongo's hands. There was absolutely no doubt that Ingagi was the dominant animal during feeding, and yet only once did I observe the slightest tendency toward ill temper, anger or pugnacity. That instance was when Ingagi took a peach from Mbongo's hands. The lack of all aggressive behavior suggesting pugnacity was striking. About two years before this study was made there is said to have been a mild

fight in which Mbongo bit Ingagi's shoulder, but nothing of that kind has been observed since.

Mbongo was dominant during play just as certainly as Ingagi controlled the situation during feeding. It was Mbongo who initiated most series of play and persisted in carrying them to a finish. Either through strength or cleverness Mbongo frequently got the better of the larger animal, Ingagi. In play, Mbongo exerted himself more, hence played harder and faster, whereas Ingagi was somewhat lazy, reluctant to exert himself and even seemed at times prone to avoid playful encounters. Their age difference may account in part for this variation.*

In the third modality of behavior, grooming, Ingagi was dominant and Mbongo passive. This is readily seen from the accounts of grooming behavior.

Two important generalizations seem to be indicated from these observations relative to dominance. First, a gorilla that is dominant in one modality of behavior and one situation may not be dominant in another modality of behavior and in another situation even with the same associate. Second, the dominance-submission relation may persist between two animals without fighting as a means of maintaining or instrumenting the relation. To what extent these generalizations hold for other primates, or even for all gorillas, remains to be determined by further observations and experiments.

Several instances of simple cooperative behavior were observed. This is an important aspect of animal economy and social life that has been greatly neglected by comparative psychologists. True social play would be impossible without an element of cooperative coordination. This quality is necessary even in behavior involving opposition or competition. The cooperative attitude was most conspicuous in the gorillas during grooming with its active and passive relationships. Without this synchronized, coordinated behavior, true grooming would have been impossible. Furthermore, I have seen the animals work together when moving the eight hundred pound log which lay in their cage. It was interesting to see the animals alternately splashing water from the pool, wetting the floor and then performing their sliding stunt on the slick

*The following is an excerpt from a letter of Mrs. Benchley's written on August 6, 1936. "In reading this paper and observing Mbongo and Ingagi,..... I am amazed at how little their actions and reactions have changed in this two year period. They are perhaps a little less playful, but very little and on the days when they are in a playful mood, their play is as continuous and spontaneous as it has ever been."

cement. These observations suggest numerous experimental procedures which may be followed in studying this important aspect of social life in the sub-human primates.

Temperament

I have found a marked inconsistency between the accounts in the literature concerning the temperament of gorillas and those qualities of behavior which I understand as temperament in the San Diego animals. Of all writers, Yerkes seems to have most clearly described the temperament of "Congo" and his description fits, in part, the temperament of Ingagi and Mbongo. As I have previously shown, most of the animals which have been accessible for study have been immature, possibly poorly handled, isolated and probably unhealthy. Difficulties in the way of field studies would seem to make it almost impossible to gain a correct impression of the temperament of gorillas in the wild. Wildness as an aspect of temperament itself interferes with the acquisition of a total conception of temperament. Yerkes writes of "Congo",

> "This section may be concluded with the characterization of the temperament and disposition of Congo as naturally shy, timid, without being cowardly, good-natured, emotionally stable and inexpressive, aloof and self-dependent, playful, moody, but more often contented and presumably satisfied with conditions than depressed and unhappy" (P. 64, 17b).

The adjectives used by Yerkes which fit the temperament of Ingagi and Mbongo are, good-natured, emotionally stable and playful, whereas words which do not fit are inexpressive, aloof, self-dependent and moody.

References in the literature which describe the gorilla as being sullen, ferocious, aggressive and melancholy are out of line with the temperament of the subjects of this study, and I am inclined to think that such descriptions may be artifacts of abnormal conditions of the subjects studied and inaccurate descriptions. Observations regarding affective expression have less validity when made on immature, poorly cared for, unhealthy or isolated specimens. The difference *in tempo* or rate of change in behavior in gorillas, which seems to me to be a typically normal characteristic of their behavior judging from the six specimens that I have seen, seems to lead to a misinterpretation of their temperament as being melancholy, gloomy or moody. However, it must be recognized that even the San Diego gorillas are atypical since they are *two young males in captivity.*

In the summer of 1934 the temperament of Ingagi and Mbongo might be described as emotionally stable, playful, fearless toward each other and toward man, seemingly deliberate and with unusual persistence of attention, somewhat sly and tricky, contented and well adapted to each other and to their captive life. They showed considerable slow, forceful spontaneity in their actions. In addition, one might say that there was a decided stubbornness and determination about their behavior. This quality of behavior might be important in consideration of gorillas as experimental subjects.

Ability to Learn

That the gorillas become quickly conditioned and learn readily is indicated by the following series of observations: For a time I attempted to separate the animals for experimental purposes. This was obviously annoying to them and indicated incidentally the strength of the attachment between the two. In order to separate them it was necessary to coax one animal into the sleeping room in the first place, and even more difficult to drop the trap door completely. The behavior of the experimenter, even slight movements, became conditioned stimuli which indicated that the door was going to be closed. If lured into the room for food, the animal would snatch it and dash out again. If I was successful in beginning to lower the door, the animal would catch it and raise it up again to its original position. He would always watch the experimenter and the slightest move toward the remote control chain would produce an immediate attempt at escape. This negative or avoidance reaction was set up after three successful separations of the animals and four or five unsuccessful attempts. This negative conditioning in the general situation made experimental work on the delayed reaction problem impossible. Little or no difficulty was experienced when both of the animals were enclosed in the sleeping room at night. Nevertheless, it has been indicated in an earlier section of this report that the animals can be conditioned readily by means of grooming and gentle treatment.

Certain vocalizations and gestures produced by one gorilla stimulated fitting responses in the other. These appropriate responses were presumably in large part learned. When Mbongo was eating and Ingagi approached, giving at the same time short rapid grunts, Mbongo would withdraw. Also, there was something about the attitude and

the way in which Mbongo postured that seemed to stimulate Ingagi to groom him.

Mbongo and Ingagi readily recognized and responded differentially to individuals. The keeper, Smith, was responded to with considerable excitement anticipatory to being fed. When the Director, Mrs. Benchley, approached even in her car, the gorillas would gallop up and down the front of their cage, grunt, protrude their lips and at times beat their chests. Whereas at first they were coolly indifferent to me, by August 15 they were positively friendly and made differential responses to me as contrasted with visitors to the cage.

Nest Building

In conclusion, I shall report incidental observations on nest building. Ingagi and Mbongo were bedded down at night with straw and invariably they made nests of this material. Typically separate nests were made in different corners of their sleeping room. Characteristically the nest was made by pulling the straw in toward their bodies and tucking it around themselves, thus forming a rough pile in which to lie.

In the St. Louis Zoological Garden in 1934 a young mountain gorilla of forty pounds weight performed the best demonstration of gorilla nest building that I have yet seen. The young animal was released in the park to play with two adolescent chimpanzees. When these began to annoy her, she ran for a tree, climbed it to the topmost branches and began to build a nest. This was done by pulling in the smaller branches and breaking them in the middle. Those secured were held while others within reach were pulled in and broken. Within three minutes there was formed a crude nest which adequately concealed the gorilla from the ground. I interpret this example of nest building as an attempt at concealment or escape from the chimpanzees. The drive for nest building in the San Diego animals was that of comfort and probably especially warmth. These observations suggest that motives for nest building are complex and that nests may serve several behavioral functions.

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THE MAXIMUM AMPLITUDE AND VELOCITY OF JOINT MOVEMENTS IN NORMAL MALE HUMAN ADULTS

BY A. DOUGLAS GLANVILLE AND GEORGE KREEZER*

I. INTRODUCTION

THE PURPOSE of the present study was to determine the maximum amplitude and velocity of movement possible at the various joints of the body in a sample group of normal male human adults. The study represents part of a more comprehensive investigation of the development of human motor functions and the nature of the deviations in these functions found to be associated with certain developmental deficiencies. The plan being followed in this more general survey is that of proceeding in successive steps of analysis from an examination of the characteristics of complex motor activities to a determination of the physiological factors on which they depend.[1]

It is apparent that all complex motor activities involve various organizations of component movements at different joints. As parts of the complex movements, the movements at individual joints vary in both amplitude and velocity. A knowledge of the raw materials of movement requires then a knowledge of the extent to which the individual joint-movements may vary in these characteristics. A first indication of the possibilities in this direction may be provided by a survey of the *limits* of variation in the movements at various joints. We have therefore attempted to determine the upper limits of amplitude and velocity of joint movement in a sample group of normal male adults.

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[1] For a brief description of this scheme for analysis of human motor functions and its relation to investigations of amplitude and velocity of joint movements, see Kreezer (23) pp. 357-363.

To facilitate the use of these data in the investigation of the motor characteristics of special groups, such as those made up of individuals at various stages of development, and groups characterized by developmental deficiencies, the results have been presented in the form of tables of norms. In our investigation of the amplitude of joint movements, practically all the joints of the body have been considered, and the extent of both voluntary and passive movements has been determined. Our investigation of the velocity of movements has been limited to an examination of voluntary movements of flexion and extension at the elbow joint on both sides of the body.

A survey of the literature reveals a surprising dearth of information upon these topics. Even where reports on the normal characteristics of joint movements are made, the material is rarely presented in a form adequate for use as standards in the investigation of other types of subjects. The values reported by Clark (1), Frescoln (4), and Silver (3) on the amplitude of joint movement, for example, are alleged merely to represent an approximately normal range of movement. There are no indications of the limits of normal variation, nor of the size or characteristics of the groups on which the average values were determined.

The data reported by Gilliland (2) and by Sinelnikoff and Grigorowitsch (5) are more satisfactory in these respects. Sinelnikoff and Grigorowitsch report the results of measurements of amplitude of voluntary movement made on a group of 100 working men between the ages of 20 and 50 and a group of healthy women of similar social position and age range. For each movement considered the authors report the arithmetical mean, standard deviation, and upper and lower limits of the distribution. The usefulness of their data as norms is limited, however, by the fact that they fail to specify the conditions under which the measurements were made, as for example, the standard positions of the joints which were taken as a starting place for the movement. These authors, it is true, were not primarily concerned with establishing norms, but wished rather to determine the influence of conditions such as sex and constitutional type on the maximum amplitude of voluntary movement at various joints.

Gilliland reports the results of measurements on the maximum range of voluntary movements made on a group of 100 male college students. For each type of movement considered the mean, average deviation, and upper and lower limits of the distribution of measures are reported. In establishing these norms, Gilliland made use of a variety of instruments, using different types of instruments for movement at different joints. The conditions of measurement are clearly stated. For joints where movements may occur in opposite directions about an assumed central position, separate norms for the "part movements" are not given, but only a combined value for the amplitude between the two limiting extremes. Thus, in connection with flexion and extension of the humerus, the author considers under the term "flexion-extension" the entire range of movement between the positions of full flexion forward and full extension backward.

Although Gilliland's methods of measurement and the norms established are satisfactory for many purposes, we felt the need for norms which could be obtained by the use of a single instrument, and which were in terms of measures of the "part movements" for joints where movement is possible in two directions about a central position. The use of a single instrument makes the carrying out of measurements on a variety of joints less cumbersome, and permits greater uniformity in the conditions of measurement. In the analysis of the rôle that joint movements may play either in the development of motor functions or in motor deficiencies, it is desirable to know the range of movement normally possible in a specific direction from a central position as well as the total range of movement at the joint.

There is apparently even less information of a normative kind on the maximum velocity of voluntary movement at the various joints than there is on amplitude. The need for such norms is at least implied, however, by a number of writers who state that one of the marked variations which occur in certain types of subjects is a variation in the speed of voluntary movement. For example, Franz (8, 40f) who gives a simple clinical method for measuring speed of movement, points out that marked variations may occur in the rapidity of movement in pathological conditions. Most of the investigations which have considered the problem of the velocity of voluntary movement have not been designed to yield data which could be used as norms of the velocity of movements at individual joints. These studies have been concerned chiefly with other problems, such as reaction times, speed of complex movements involving two or more joints, effect of load on the speed of movement, or the nature of the factors underlying the speed of relatively complex voluntary movements (e.g. 24-29).

II. SUBJECTS

The norms for the amplitude and the velocity of joint movements given in the present paper were obtained on 10 male mentally normal subjects between the ages of 20 and 40. Nine of the subjects were employees of the Vineland Training School (4 teachers in the school, 3 members of the laboratory staff, and 1 a cottage attendant) and 1 was engaged in private business. None of these subjects showed any apparent motor disorders. The average height of the group was 5 ft. 9 in., with a range from 5 ft. 4 in. to 6 ft. 1 in.; average weight was 143 pounds with a range from 120 to 172 pounds. All subjects were right handed as determined by means of Lauterbach's inventory for the determination of handedness (30).

III. METHOD

A. Measurement of amplitude of joint movement

Measuring instrument. The same instrument was used for making all measurements of amplitude of joint movement. Its construction and

manner of use are illustrated in Figure 1. Its operation is based on the relative movement produced between the circular scale (d), fixed in position relative to the moving member, and the plumb line provided by the pendulum (a).[2] The instrument is light in weight, does not interfere with free movement, can be easily and quickly adjusted, and kept securely in position throughout the entire range of movement.

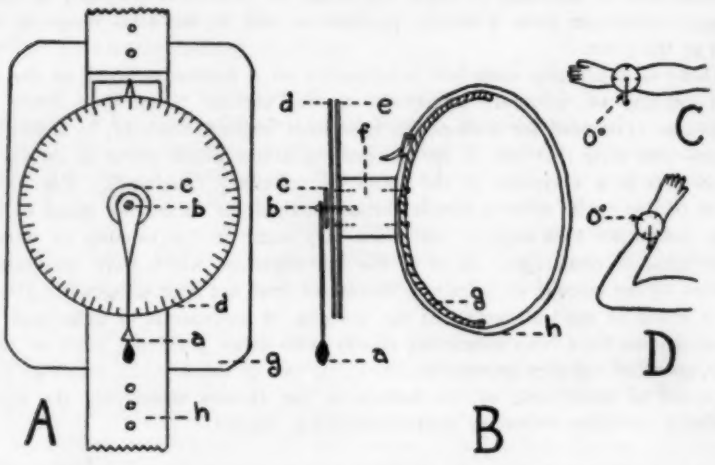

FIG. 1. SHOWING CONSTRUCTION AND MANNER OF USE OF PLUMB-LINE GONIOMETER.

(*A*) Front view. (*B*) Diagrammatic side view. (*C*) Instrument in place on forearm with extension at elbow. (*D*) Instrument in place on forearm with flexion at elbow.

Parts: (*a*) weighted metal pendulum, which serves as indicator, drawn to fine edge at point where reading on dial is taken; (*b*) pivot from which *a* is suspended, attached to block *f*; (*c*) smooth, thin metal washer between pendulum and graduated dial *d*, to provide space between *a* and dial *d* and thus decrease friction; (*d*) adjustable metal dial which, when set at zero point, is fixed to *e*; (*e*) metal disc fastened to *f* and serving as a rigid back for the movable dial; (*f*) block of light wood, ¾″ × 1′ × 3½″; (*g*) thin, flexible lead strip which can be shaped to fit contour of limb and thereby help to hold instrument securely in place; (*h*) broad, soft leather strap with which instrument is fastened securely but not tightly to the limb.

[2] A similar principle is used in the instrument employed at the Walter Reed Hospital, Washington D. C., for measurements of movements at the shoulder joint.

TABLE 1

Conditions Operative in Measurements of Joint Movement

1 Part Moved and Movement	2 Position of Subject	3 Initial Position of Part Moved	4 Placement of Instrument	5 Accessory Movements Avoided
I. *Head*				
a. Vent. Flex.	Supine	Head erect relative to trunk, i.e. caudal surface of mandible perpendicular to long axis of trunk	Lat. surface of head	Of shoulders and trunk
b. Dors. Flex.	Prone		Same as Ia	Same as Ia
c. Lat. Flex.	Sitting erect		Dors. surface of head	Same as Ia
d. Rotat.	Supine		Cranial surface of head	Same as Ia
II. *Upper arm*				
a. Flex. (forw.)[1]	Supine Shoulder over edge of table	Parallel to axis of trunk, forearm extended, hand in thumb-up position	Lat. surface of arm just prox. to elbow	Flexion of forearm
b. Exten. (bkw.)	Prone Shoulder over edge of table	Same as IIa, except hand in thumb-down position	Same as IIa	Same as IIa and movements of shoulder
c. Abduct.	Lies on side, fully extended	Forearm extended, with palm on thigh	Dors. surface of upper arm just prox. to elbow	Deviations from lat. plane
d. Int. Rot.	Supine	Humerus abducted to 90° to trunk, forearm flexed 90° at elbow and held vertical	Ulnar surface just prox. to wrist	Raising of elbow
e. Ext. Rot.	Supine	Same as IId.	Same as IId	Same as IId
III. *Forearm*				
a. Flex.	Supine	Same as IIa	Dors. surface just prox. to wrist	Flexion of humerus
b. Pronat.	Sitting erect	Flexed 90° at elbow, resting on arm-rest, thumb up, fingers flexed	Loop of strap grasped in hand, instrument perpendicular to long axis of arm	Abduction of humerus and lat. movements of trunk
c. Supinat.	Sitting erect	Same as IIIb	Same as IIIb	Same as IIIb
IV. *Hand* (at wrist)				
a. Flex. (palmar)	Sitting erect	Same as IIIb, except palm down on horizon. rest, fingers extended	Ulnar surface of hand	Flexion of fingers and raising of elbow
b. Exten. (dors.)	Sitting erect	Same as IVa	Same as IVa	Raising of forearm from arm-rest
c. Abduct. (rad. flex.)	Sitting erect	Same as IIIb, except fingers extended	Dors. surface of hand	Raising of forearm from arm-rest or flexion
d. Adduct. (uln. flex.)	Sitting erect	Same as IVc	Same as IVc	Raising of elbow or flexion of fingers

TABLE 1—*Continued*

1 Part Moved and Movement	2 Position of Subject	3 Initial Position of Part Moved	4 Placement of Instrument	5 Accessory Movements Avoided
V. *Thigh*				
a. Flex. (forw.)[2]	Supine	Horizontal	Lat. surface of thigh just prox. to knee	Raising any part of trunk
b. Exten. (bkw.)	Prone	Horizontal, leg extended	Same as Va	Same as Va and assistive movements of other leg
c. Abduct.	Lies on side, fully extended	Continuous with long axis of trunk, leg extended, resting on other leg	Dors. surface of thigh just prox. to knee	Flexion or rotation at hip
d. Int. Rot.	Prone	Femur continuous with long axis of trunk, lower leg flexed to 90° and held vertical[3]	Vent. surface of leg just prox. to ankle	Abduction or adduction at hip
e. Ext. Rot.	Prone	Same as Vd	Same as Vd	Same as Vd
VI. *Lower Leg*				
a. Flex.	Prone	Horizontal to surface of table, foot beyond end of table	Lat. surface just prox. to ankle	Hyper-extension of humerus
VII. *Foot* (at ankle)				
a. Plant. Flex.	Supine	Caudal surface of foot vertical. Foot beyond end of table	Lat. edge of foot	Flexion at knee
b. Dors. Flex.	Supine	Same as VIIa	Same as VIIa	Same as VIIa

[1] Movement of scapula permitted in order to obtain maximal movement.

[2] With flexion of lower leg.

[3] Other leg abducted in order not to interfere with full range of movement of leg being measured.

In measuring pronation and supination of the forearm and all the movements of the hand, an arm-rest was used. This rest consisted of a horizontal rectangular platform which was attached at the ends to vertical supports so that it could be placed over the lap of the subject. To facilitate the proper attachment of the goniometer for the measurement of the movements of the hand the platform was equipped with horizontal extensions on which the hand could be rested and which could be pushed out of the way when the measurements were made.

Procedure. Whenever possible, the measurements were taken with the subject lying in a supine or a prone position on a thin mattress placed on a table.[3] After the subject had assumed the proper position, the instrument was attached at the proper point, and with the limb placed in the adopted initial position, the graduated dial of the instrument was set so that its zero point was opposite the

[3] We had our subjects lie down, since many of the crippled patients with whom we wished to use the norms were unable to sit or stand stably enough to enable us to take accurate measurements.

edge of the indicator. Three readings were taken of the amplitude of each movement examined. Separate measurements were taken for voluntary and passive movements on both the right and left sides of the body. When passive movements were measured the subject was instructed to relax and the examiner moved the limb as far as it would go. The examiner applied the force at the same point and attempted to use the same maximum force with all subjects. One examiner made all measurements (GL).

In order to prevent assistive or associated movements at neighboring joints from influencing the measurements, and at the same time to avoid the artificial situation produced when the subject's limbs are strapped in a fixed position, the examiner either held the neighboring parts in the proper position, or, when this was not feasible, took the reading on the instrument at the point just before assistive movements were observed to occur. The subjects were instructed to perform all active movements with maximum effort and to avoid assistive movements or changes of gross bodily position. Subjects were measured only when they were in good health and were not fatigued by previous activities.

In Table 1 are given the special conditions operative in the measurement of the various movements. These were adopted as a result of preliminary trials. The first four columns are self-explanatory. In the last column are indicated the movements which the subject tended to make other than movements being measured, and which precautions were taken to avoid.

B. *Measurement of velocity of joint movement*

In the present study we have confined our measurements of the velocity of movement to movements of flexion and extension at the elbow joint. Since measurements of velocity of movement at the joints are somewhat more cumbersome than measurements of amplitude of movement, our choice of movements has been dictated principally by convenience. The same apparatus and procedure might be used with but slight modifications, for measurements at other joints, and preliminary trials show that they are easily adapted for measurements at the knee joint.

The essential features of the procedure used involved (1) immobilization of the upper arm, (2) suspension of the forearm just above the wrist so that it moved in a horizontal plane, (3) kymographic recording of the movement performed when the subject voluntarily flexes or extends his forearm in the horizontal plane at the maximal velocity, and (4) computation of the average velocity of movement from the kymographic record.

Apparatus.[4] The chair in which the subject sits is equipped with an adjustable arm-rest which immobilizes the upper arm as comfortably as possible in a

[4] A more detailed description of the apparatus will appear in a report to be published later upon investigations of muscle tonus, in which the same apparatus with slight modifications was used.

position such that the upper arms slightly abducted so as to make an angle of about 30° with a saggital plane through the body and forms an angle (downward) of approximately 10 degrees with the horizontal. A leather cuff fits snugly around the subject's forearm just above the wrist. This cuff is attached to a light metal chain which is suspended from the ceiling at a point directly above the elbow joint. With the arm suspended in this manner, the forearm moves freely in a horizontal plane and the influence of gravity on the speed of movement is thus avoided. The arm is connected at the cuff by means of a pliable and inelastic cord to a system of levers. The first lever serves to reduce by a known ratio the amplitude of the movement transmitted to the second or recording lever. The arm of the recording lever which carries the writing point is relatively long (40 cm.) so that the arc described on the kymographic paper has a relatively large radius. There is thus a reduction in the distortion of the record produced by the arc through which the writing point moves. The mass and friction of the moving parts of the recording system are kept small so that they will not retard appreciably the free movement of the arm or distort the records obtained. An electrically driven time-marker writes a time-line in sixtieths of a second on the record.

Procedure. After the subject was properly placed in the apparatus, the arm was placed against a block which was adjusted so that the arm would always start its movement from the same initial angular position. In movements of flexion the forearm started from an initial position of 15 degrees of flexion: in movements of extension, the forearm started from an initial position of 90 degrees of flexion.

Ten records were taken for each subject for each of the movements of flexion and extension of both left and right arms. The subjects were instructed to make movements as rapidly as possible throughout the entire range of the movement. At each trial, the preparatory signal "Ready" was given about one second before the final signal "Now" at which the subject was to execute the movement.

Analysis of Records. The records obtained by the method described above were analyzed to provide measures of the average velocity of a given movement over the initial 45° of arc traversed by the arm. In all determinations the necessary correction was made for the slight distortion introduced into the records through the fact that the writing point describes an arc. Although the range of movement executed by the arm was always greater than 45°, this range was selected as providing an adequate basis for determination of average velocity. A measure of average velocity on this basis takes into account, without giving it undue weight, the increase in velocity which is known to occur at the beginning of voluntary movements performed at the maximum speed of which the subject is capable (29). A range of movement of 45° for the arm also has the advantage of lying within the range of the maximum amplitude of voluntary movement of many of the subjects suffering from deficient motor functions whom we have examined in connection with other studies.

IV. RESULTS

A. Maximum amplitude of joint movements

The results of the measurements of the maximum amplitude of voluntary and passive joint movements are summarized in Table 2.

For each type of movement there is given separately for the right and left sides of the body (1) the smallest amplitude found in any individual, (2) the greatest amplitude found in any individual, (3) the average (arithmetical mean) amplitude for the group, and (4) the standard deviation of the distribution of measures. In computing these statistics the amplitude of movement for each subject was taken as the average of the three measures made for each movement of the subject.

Columns 5, 6, and 11 are intended to indicate the degree of precision that may be expected with the method of measurement described in the present paper. Columns 5 and 11 give, for the voluntary and passive movements, respectively, the estimated average probable error of a single measure for each of the various movements, as estimated by means of a procedure described below. Column 6 gives the probable error of a single measure as determined in four representative voluntary movements of one subject chosen as a sample. A comparison of the estimated average values of the probable errors of a single measure, for the entire group of subjects, and the values determined on one particular subject, on the basis of a relatively large number of trials, shows them to be of the same order of magnitude, and that the estimated average values can therefore be accepted as indicating, to a fair approximation, the precision of measurement which may be obtained with the present method.

The following procedure was used for obtaining an estimate of the average probable error of a single measurement for each of the various movements. For *each* of the 10 subjects, the amount by which each of the three measures made deviated from the arithmetical mean of the three measures was determined. The 30 deviations thus obtained for the whole group were regarded as representative of the distribution of deviations that would be found if 30 measures of any one individual of the group were made. A probable error based on these 30 deviations was then calculated in the usual way. We refer to the probable errors thus obtained as estimates since the deviations used as a basis for the calculations were not actually deviations all found in any one individual.

The values listed in Column 6 were obtained in one subject of the group chosen at random. In this subject 30 measures of the maximum amplitude of movement were made for each of four voluntary movements examined and the corresponding probable error of the single measurement computed. In order to avoid fatigue in the subject and to determine the influence of possible variations in the subject from day to day, half of each section of the 30 measures was made on different (successive) days. The differences between the averages of the two days were not found to be statistically significant.

TABLE 2

Amplitude of Voluntary and Passive Movements at Various Joints of Adult Males without Motor Disorder[1]

COLUMN NO.			1	2	3	4	5	6	7	8	9	10	11
			VOLUNTARY						PASSIVE				
PART MOVED	MOVEMENT	SIDE	LOWER LIMIT	UPPER LIMIT	ARITH. MEAN	σ DIST.	P.E. EST.	P.E. OBT.	LOWER LIMIT	UPPER LIMIT	ARITH. MEAN	σ DIST.	P.E. EST.
Head (relative to trunk)	Vent. Flex.		41.6	73.3	59.8	11.7	.54		65.3	91.0	76.4	9.2	.55
	Dors. Flex.		22.3	109.3	61.2	26.8	.70		40.3	115.0	77.2	25.1	.22
	Lat. Flex.	R	34.3	54.3	39.4	6.0	.45		51.3	80.6	60.7	8.2	.36
		L	29.6	55.3	42.9	7.7			46.6	82.3	64.8	9.7	
	Rotat.	R	50.6	95.0	77.2	16.1	.63		72.3	114.0	96.6	14.1	.67
		L	58.6	93.6	79.8	12.8			70.0	105.3	95.4	11.1	
Arm (at shoulder joint)	Flex. (forw.)	R	164.3	191.0	179.0	7.2	.45		172.3	195.3	184.6	6.4	.33
		L	165.3	187.3	179.9	6.3			173.3	195.0	185.4	6.2	
	Exten. (bkw.)	R	40.0	71.0	55.2	10.1	.45		51.0	93.3	67.7	11.9	.41
		L	33.6	75.0	60.0	12.4			56.0	85.0	70.3	10.2	
	Abduct.	R	113.0	154.3	129.3	11.7	.60		116.0	163.0	136.7	12.4	.46
		L	112.6	145.0	130.3	11.2			123.3	155.0	137.2	12.1	
	Int. Rot.	R	59.0	129.3	94.1	22.1	.59		65.6	135.0	101.1	22.5	.34
		L	80.0	130.6	100.0	16.3			90.0	135.0	108.0	14.1	
	Ext. Rot.	R	60.0	92.6	82.7	10.0	.55		78.0	100.3	92.0	7.2	.63
		L	47.6	109.3	83.5	16.2			61.3	115.0	92.2	13.9	
Fore-arm (at elbow joint)	Flex.	R	125.6	150.3	138.3	8.5	.47	.63	129.3	155.0	143.2	7.6	.24
		L	132.3	156.3	144.2	8.9			135.0	157.6	147.9	7.8	
	Pronat.	R	59.0	139.0	91.1	25.8	.94	1.01	75.6	145.0	104.9	22.1	.60
		L	69.0	134.6	93.0	20.7			89.3	145.0	111.2	15.1	
	Supinat.	R	81.3	114.0	99.4	11.0	.88	1.34	92.6	145.0	114.3	15.2	.60
		L	74.0	114.3	100.6	10.8			97.3	141.6	116.0	13.0	
Hand (at wrist joints)	Flex. (palmar)	R	73.0	109.6	95.0	10.6	.66		80.3	122.0	105.6	13.0	.54
		L	75.0	110.0	90.0	9.8			92.0	122.6	103.3	10.6	
	Exten. (dors.)	R	32.0	80.3	54.1	15.2	.61		67.0	110.6	91.8	13.0	.55
		L	46.3	85.3	65.7	12.6			69.3	135.0	104.2	19.0	
	Abduct. (rad. fl.)	R	15.0	40.0	27.1	7.1	.35		26.0	47.0	39.7	6.1	.36
		L	17.6	44.3	31.1	8.4			24.0	58.3	45.4	9.6	
	Adduct. (uln. fl.)	R	52.0	78.6	66.1	8.1	.65		63.6	85.0	74.1	7.4	.51
		L	53.0	84.0	66.1	8.8			65.0	85.3	74.5	6.7	

TABLE 2—*Continued*

COLUMN NO.			1	2	3	4	5	6	7	8	9	10	11
			VOLUNTARY						PASSIVE				
PART MOVED	MOVEMENT	SIDE	LOWER LIMIT	UPPER LIMIT	ARITH. MEAN	σ DIST.	P.E. EST.	P.E. OBT.	LOWER LIMIT	UPPER LIMIT	ARITH. MEAN	σ DIST.	P.E. EST.
Thigh (at hip joint)	Flex. (forw.)	R	63.0	119.3	97.8	17.0	.63		99.3	123.6	111.5	9.2	.59
		L	91.0	115.0	105.6	8.3			99.3	127.0	112.9	9.6	
	Exten. (bkw.)	R	26.0	70.3	48.4	12.9	.66		40.6	74.6	56.4	10.4	.40
		L	26.3	59.3	42.4	9.9			35.3	61.3	52.1	8.2	
	Abduct.	R	39.3	97.6	70.1	17.0	.74		65.3	101.0	79.3	10.4	.40
		L	41.6	88.0	71.7	14.1			60.0	95.3	79.4	10.0	
	Int. Rot.	R	39.0	80.3	60.6	15.2	.59		45.3	90.0	73.0	16.6	.41
		L	42.3	90.0	66.3	13.5			50.3	90.0	76.2	14.5	
	Ext. Rot.	R	24.0	48.0	37.0	6.6	.60		39.0	60.3	45.6	6.7	.44
		L	16.0	43.3	30.4	8.3			25.3	54.6	39.2	8.4	
Leg (at knee joint)	Flex.	R	118.0	136.0	126.6	6.7	.53	.93	128.3	150.0	139.9	6.8	.51
		L	114.0	136.3	123.7	6.7			120.3	145.0	136.3	7.6	
Foot (at ankle joint)	Plant. Flex.	R	18.3	42.6	28.2	7.4	.74		21.6	55.0	36.1	9.9	.36
		L	15.0	43.0	26.2	8.9			21.6	57.6	35.3	11.2	
	Dors. Flex.	R	25.0	46.3	36.8	6.6	.45		34.6	52.0	43.9	4.7	.39
		L	24.6	51.0	39.5	8.3			30.0	55.0	44.5	7.4	

[1] Measurements in angular degrees.

B. Maximum velocity of joint movement

The results of the measurements of the maximum average velocity of the flexion and extension movements at the elbow joint are summarized in Table 3. Here too, the arithmetical mean, standard deviation of the distribution, and upper and lower limiting values for the group of normal subjects are reported. In computing these statistics, the value taken to represent the average velocity of angular movement through a range of 45 degrees, for each subject, was the arithmetical mean of the 10 measures made for each movement of the subject.

In Columns 5 and 10 there is given the obtained probable error of a single measure for each of the movements examined as determined in the usual way from 10 measures on a single subject. The subject chosen as a sample was the one who tended to show the greatest deviation from one measure to another. In the case of this subject, the

probable error of measurement was in all cases less than 6 per cent of the measure obtained.

TABLE 3

Average Velocity in Degrees per Millisecond of Voluntary Movements of Adult Males without Motor Disorders

COLUMN NO.		1	2	3	4	5	6	7	8	9	10
		RIGHT					LEFT				
PART MOVED	MOVEMENT	LOWER LIMIT	UPPER LIMIT	ARITH. MEAN	σ DIST.	SAMPLE P.E. OF A MEAS. OBT.	LOWER LIMIT	UPPER LIMIT	ARITH. MEAN	σ DIST.	SAMPLE P.E. OF A MEAS. OBT.
Forearm (at elbow joint)	Flex.	.263	.602	.425	.108	.016	.212	.683	.444	.136	.036
	Exten.	.356	.575	.448	.069	.030	.304	.823	.500	.147	.010

V. COMMENT

The tables of results given above are intended to serve as norms of the amplitude of movement at the joints and of average velocity of voluntary flexion and extension at the elbow. It is to be noted, however, that these tables of norms, since they are not based on a large group of subjects, are to be regarded as but a first approximation to the values that would probably be obtained with a larger group. Errors of sampling are probably involved to some extent. It should also be borne in mind that these norms may be legitimately used as standards in the investigation of the motor characteristics of special groups only when the measurements are made under the same conditions as those used for determining the norms. Measurements of the amplitude and velocity of movement of the forearm, for example, may vary considerably depending upon the position in which the upper arm is held while the movements are executed.

In the tables given, a magnitude of primary importance is the lower limiting value for a particular movement. The occurrence of an amplitude or velocity of movement equal to or greater than this value would indicate that the individual's measure fell within the "normal" range. Examination of Table 2 shows that for some movements this lower limiting value may fall only about 10° below the average for the

group, while for other movements it may fall as much as 25° below the average amplitude. This variability indicates the inadequacy of tables of "norms" limited to a statement of average values.

VI. SUMMARY

1. In the present paper norms are presented (a) of the maximum amplitude of voluntary and passive movements occurring at various joints of the body, and (b) of the maximum velocity of voluntary flexion and extension at the elbow joint of normal male adult subjects. These norms were determined in order to provide standards that might be used in the investigation of the motor characteristics of special types of individuals, particularly those representing different stages of development, and various developmental deficiencies. Such data on the maximum amplitude and velocity of movement possible at the various joints indicate the limiting values of the raw materials which enter as components in all complex motor activities.

2. Measurements of amplitude at all joints were made with the same instrument, a plumb-line goniometer, whose operation depends on measurements of the relative movement occurring between a plumb-line and a circular scale fixed to the moving member. The precision of measurement possible with the instrument is represented by a probable error for the single measure of the order of 0.5°.

3. Measurements of maximum velocity were obtained from kymographic records of voluntary movement made by flexing or extending the forearm at the elbow joint in a horizontal plane. The precision of measurement obtained in these measurements is represented by a probable error for the single measure under 6 per cent.

4. A bibliography of work on the amplitude of joint movement is appended in view of the lack of an adequate review of this field in the literature. The references given relative to velocity of movement are intended to illustrate the types of investigations that have been made in this field. We have not come across previous investigations which provide data suitable for use as norms of velocity of movement at individual joints.

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VARIATION IN PARITY OF WOMEN BEARING CHILDREN IN THE U. S. BIRTH REGISTRATION AREA IN 1930. PART II[1]

BY RAYMOND PEARL

VI. PARITY AND AGE

THE question to be discussed in this section concerns the biometric analysis of the variation in parity order of births of 1930 relative to age of mother. The basic biometric constants are given in Tables 15-17 inclusive. Questions to which answers are desired are of the following sort: Given a group of women aged 30-34 years, for example, all bearing children in a particular year, what will be the mean or median parity order of their births in that year? What degrees of variation, absolute and relative, will they exhibit in parity? With this material at hand it will be possible, in connection with the data already presented in Part I, to examine the phenomena of parity from the alternative and opposite points of view of variation in mother's age relative to specific parity on the one hand, and variation in parity relative to specific mother's ages (in five year groupings).

The means for live births from Tables 15-17 are shown graphically in Fig. 4.

The mean and median parity orders rise with each age class of mothers from 10-14 up to and including 45-49. Prior to the age class 25-29 this increase of average parity with age is more gradual; after age 30 the rise is nearly linear up to 50. The small number of women aged 50-54 years who bore children in 1930 showed, in all nativity-race(color) groups lower mean and median parities than the women in the 45-49 age class. This is true of any year's births, so far as I have examined

[1] From the Department of Biology of the School of Hygiene and Public Health, Johns Hopkins University, Baltimore, Maryland.

The first part of this study appeared in HUMAN BIOLOGY, Vol.. 9, pp. 65-98, 1937. The numbering of the sections, tables, and illustrations in this concluding part continues the numbering of the first part.

TABLE 15

Biometric constants for variation in parity order of births in 1930 to native white women, by age

A. Live births

AGE (*years*)	*N*	MEAN PARITY ORDER	MEDIAN	ST. DEV.	C. OF V.
10-14	1,222	1.004±.0012	1.002±.0015	0.064±.0009	6.36±.09
15-19	195,289	1.239±.0008	1.130±.0009	0.507±.0006	40.96±.05
20-24	495,428	1.878±.0010	1.628±.0013	1.044±.0007	55.57±.05
25-29	402,373	2.826±.0018	2.479±.0022	1.645±.0012	58.19±.06
30-34	266,714	4.039±.0030	3.670±.0037	2.286±.0021	56.59±.07
35-39	160,941	5.534±.0049	5.266±.0061	2.904±.0035	52.46±.08
40-44	52,257	7.199±.010	7.161±.013	3.401±.007	47.24±.12
45-49	4,556	8.715±.037	8.905±.046	3.660±.026	42.00±.35
50 and over	76	6.868±.294	6.500±.368	3.802±.208	55.4 ±3.9

B. Stillbirths

10-14	63	1.000	1.000	0	0
15-19	6,506	1.208±.004	1.102±.005	0.512±.003	42.4±.29
20-24	12,762	1.757±.007	1.372±.008	1.116±.005	63.5±.36
25-29	9,861	2.820±.013	2.348±.016	1.908±.009	67.7±.45
30-34	7,728	4.092±.020	3.663±.025	2.614±.014	63.9±.47
35-39	6,274	5.622±.028	5.382±.035	3.240±.020	57.6±.45
40-44	2,742	7.241±.048	7.213±.061	3.754±.034	51.8±.58
45-49	333	8.553±.152	8.867±.190	4.115±.108	48.1±1.52
50 and over	2	9.50 ±2.62	9.50 ±3.28	5.50 ±1.85	57.9±25.2

them. It is a curious fact, probably chiefly reflecting a considerably reduced ovulation rate in the women whose menopause is postponed into the fifties.

The most striking single feature of Tables 15-17 and Fig. 4 is perhaps the relatively large superiority in mean and median parities of the colored group over the native and foreign-born white groups at all ages (except for the means at 50 and over, where the colored fall insignificantly below the foreign-born whites). The two white groups are not greatly differentiated from each other at any ages in mean or

TABLE 16

Biometric constants for variation in parity order of births in 1930 to foreign-born white women, by age

A. Live births

AGE (*years*)	*N*	MEAN PARITY ORDER	MEDIAN	ST. DEV.	C. OF V.
10-14	15	1.000	1.000	0	0
15-19	7,839	1.263±.0042	1.137±.0053	0.554±.0030	43.9± .28
20-24	44,523	1.815±.0035	1.480±.0044	1.087±.0025	59.9± .18
25-29	63,519	2.641±.0044	2.251±.0055	1.638±.0031	62.0± .16
30-34	54,665	3.940±.0067	3.464±.0084	2.304±.0047	58.5± .15
35-39	41,917	5.807±.0099	5.489±.0124	3.009±.0070	51.8± .15
40-44	15,989	7.647±.018	7.659±.023	3.414±.013	44.6± .20
45-49	1,608	8.968±.063	9.130±.078	3.724±.044	41.5± .57
50 and over	28	8.250±.612	7.000±.767	4.800±.433	58.2±6.79

B. Stillbirths

10-14	0	..	..	..	..
15-19	189	1.280±.030	1.130±.038	0.618±.021	48.3±2.0
20-24	789	1.831±.030	1.385±.038	1.233±.021	67.3±1.6
25-29	1,192	2.766±.039	2.218±.049	1.984±.027	71.7±1.4
30-34	1,424	4.249±.050	3.747±.063	2.778±.035	65.4±1.1
35-39	1,617	6.299±.056	6.052±.070	3.353±.040	53.2± .8
40-44	872	8.111±.083	8.117±.104	3.645±.059	44.9± .9
45-49	115	9.270±.259	9.000±.325	4.121±.183	44.5±2.3
50 and over	0	..	..	..	..

median parity, and while some of the differences are statistically significant in comparison with their probable errors a common sense view would seem to be that no important real biological differentiation is represented here. Therefore in order to reach a reasonable judgment of the magnitude of the departure of the colored mothers from the whites in the respect under discussion Table 18 has been prepared. The procedure in forming this table for live births has been (a) to take a weighted average of the mean and median parities of the two white groups, the weighting being on the basis of the numbers involved; (b)

to take the differences (absolute and as percent of the white averages) between these averaged mean and median parities for the whites and the corresponding mean and median colored parities; and (c) to compute the probable errors of these differences on the assumption that the probable errors of the white averages are the same as those of the

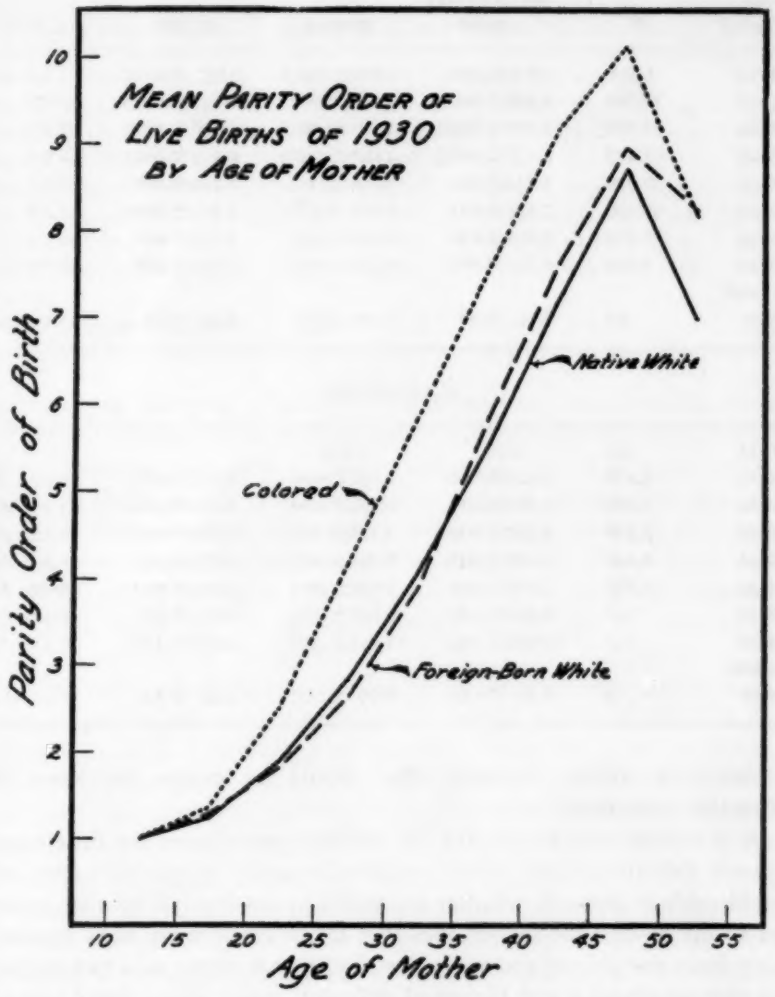

FIG. 4. MEAN PARITY ORDER OF LIVE BIRTHS IN U.S.B.R.A., BY AGE OF MOTHER

TABLE 17

Biometric constants for variation in parity order of births in 1930 to colored women, by age

A. Live births

AGE (*years*)	*N*	MEAN PARITY ORDER	MEDIAN	ST. DEV.	C. OF V.
10-14	1,521	1.003±.0010	1.002±.0013	0.057.±.0007	5.7± .07
15-19	54,804	1.348±.0018	1.190±.0023	0.642±.0013	47.6± .12
20-24	78,196	2.479±.0034	2.231±.0043	1.408±.0024	56.8± .12
25-29	51,223	4.179±.0063	4.025±.0079	2.129±.0045	50.9± .13
30-34	32,379	5.852±.010	5.796±.013	2.729±.007	46.6± .15
35-39	22,239	7.538±.015	7.581±.018	3.256±.010	43.2± .16
40-44	6,775	9.161±.030	9.296±.037	3.615±.021	39.5± .26
45-49	1,034	10.131±.082	10.379±.103	3.921±.058	38.7± .65
50 and over	41	8.19 ±.48	7.40 ±.60	4.54 ±.34	55.4±5.24

B. Stillbirths

10-14	132	1.000	1.000	0	0
15-19	4,268	1.423±.008	1.218±.010	0.755±.006	53.0± .48
20-24	5,496	2.563±.015	2.193±.019	1.625±.010	63.4± .55
25-29	3,428	4.393±.029	4.176±.036	2.482±.020	56.5± .59
30-34	2,246	6.208±.045	6.099±.057	3.179±.032	51.2± .64
35-39	1,786	7.596±.059	7.650±.074	3.695±.042	48.6± .67
40-44	641	9.460±.107	9.820±.134	4.009±.076	42.4± .93
45-49	117	11.034±.254	11.455±.318	4.074±.180	36.9±1.83
50 and over	5	6.80 ±1.03	8.00 ±1.29	3.43 ±.73	50.4±13.2

foreign-born white. Actually they would of course be lower if accurately determined.

It is evident that except for the terminal age classes the differences between the colored and white mothers in parity at specified ages are considerable in amount, whether estimated in absolute or relative terms, and so far beyond the magnitudes that might conceivably have resulted solely from the play of chance in sampling that it seems safe to conclude that they represent a real biological differentiation. *The colored women who bore living children in 1930 exhibited in their reproductive per-*

TABLE 18

Superiority of colored mothers over white in mean and median parities of live births in 1930

AGE CLASS	WHITE AVERAGE		ABSOLUTE EXCESS OF COLORED		PERCENTAGE EXCESS OF COLORED		EXCESS ÷ P.E.	
	Means	Medians	Means	Medians	Means	Medians	Means	Medians
10-14	1.004	1.002	—.001	0	—0.1	0	..	..
15-19	1.241	1.130	.107	.060	8.6	5.3	23	10
20-24	1.873	1.616	.606	.615	32.3	38.1	124	99
25-29	2.801	2.448	1.378	1.577	49.2	64.4	179	164
30-34	4.022	3.635	1.830	2.161	45.5	59.4	153	139
35-39	5.590	5.312	1.948	2.269	34.8	42.7	108	104
40-44	7.304	7.259	1.857	2.037	25.4	28.1	53	46
45-49	8.781	8.964	1.350	1.415	15.4	15.8	13	11
50 and over	7.240	6.635	.950	.765	13.1	11.5	1.2	0.8

formance of that year mean and median parities from 5 to 64 percent higher than those exhibited by the white women who bore living children in the same year, at all ages from 15 to 54 years. The same result in principle would be got if the birth figures of any other recent year were to be analyzed in the same way. Furthermore if attention is focussed on the women who produced stillbirths in 1930 (the *B* halves of Tables 15-17) it will be seen that a corresponding table to Table 18 constructed for them would lead to the same results in principle as those derived from the mothers of live births.

The standard deviations of the parity distributions are uniformly *higher* for the colored mothers of live births in all age classes from 15-19 up to and including 45-49, than for either the native or foreign-born white mothers, and in the 50 and over year class the colored standard deviation is higher than the native white, though a little lower than the foreign-born white. This would not unreasonably be expected in view of the higher mean and median parities in the colored group. The excess of the colored standard deviations over those for the whites is, however, generally not as great proportionally as the excess in the means and medians. This results in *smaller* values for the coefficients of variation in the colored group in all the age classes from 25-29 through 45-49, indicating a tendency towards lower *relative* variability

in respect of parity among the colored than among the whites. And in the 20-24 and 50 and over age classes the coefficient of variation for the colored is lower than that for the foreign-born white.

We turn next to a more particular examination of the rate of ascent of mean parity with advancing age of mothers in the several groups. After considerable deliberation over the matter and the trial of various alternative plans the following scheme has been adopted as a first step to make clear what appears to be important relations in a complicated mass of figures and biological considerations. As a preliminary step let us consider what the mean parity relations to advancing age would be in a group of women postulated to be performing reproductively throughout their total span of physiologically possible reproductive potentiality at something approaching the maximum limit of harmless physiological capacity. A fair postulate of this sort would be that starting with women producing on the average one birth in the age period 10-14 (on the ground that a certain number of females do just that in each year's birth statistics), if in each five-year period of age thereafter each woman produced two births — an average spacing of 2.5 years between births which is generally regarded as reasonable hygienically — it would result that the mean parity for the age period 15-19 would be three, for the period 20-24 five, and so on to 15 for the age period 45-49. There is no point in including the meager and

TABLE 19

Percentages of observed to theoretically postulated mean parity orders of birth by age of mother

AGE CLASS	POSTULATED MEAN PARITY	PERCENTAGE OF ACTUAL TO POSTULATED MEAN PARITY					
		Native white		Foreign-born white		Colored	
		Live	Still	Live	Still	Live	Still
10-14	1	100.4	100.0	100.0	..	100.3	100.0
15-19	3	41.3	40.3	42.1	42.7	44.9	47.4
20-24	5	37.6	35.1	36.3	36.6	49.6	51.3
25-29	7	40.4	40.3	37.7	39.5	59.7	62.8
30-34	9	44.9	45.5	43.8	47.2	65.0	69.0
35-39	11	50.3	51.1	52.8	57.3	68.5	69.1
40-44	13	55.4	55.7	58.8	62.4	70.5	72.8
45-49	15	58.1	57.0	59.8	61.8	67.5	73.6

essentially abnormal data for the age class 50 and over in the comparisons from this point on. The material already presented in this paper shows that the few women bearing children after 50 do not exhibit reproductive histories that statistically fit in with those of younger women. They are evidently a differentiated group.

How then did the actual mean parity performance of the several groups in 1930 compare with this postulated "ideal" performance? Table 19, and Fig. 5 give the answer to this question.

It is evident that the greatest departures from the postulated ideal performance in respect of mean parities occur in the two age periods between 15 and 24 years as limits. Starting all even for the 10-14 year old mothers the curves drop abruptly to mean parities in the next age group of around 40 percent of the ideal. This drop is probably connected with age at marriage, or rather with its postponement.

TABLE 20

Biometric constants for variation in parity order of births in 1930 to native white multiparae, by age

A. Live births

AGE (*years*)	*N*	MEAN PARITY ORDER	MEDIAN	ST. DEV.	C. OF V.
15-19	40,339	2.156±.001	2.077±.002	0.431±.001	19.99± .05
20-24	267,554	2.625±.001	2.366±.002	.895±.001	34.10± .03
25-29	304,552	3.413±.002	3.091±.002	1.469±.001	43.05± .04
30-34	233,871	4.466±.003	4.087±.004	2.116±.002	47.39± .06
35-39	150,618	5.845±.005	5.538±.006	2.739±.003	46.86± .07
40-44	50,344	7.435±.010	7.347±.012	3.239±.007	43.56± .11
45-49	4,432	8.931±.035	9.054±.044	3.473±.025	38.89± .32
		B. Stillbirths			
15-19	1,102	2.228±.011	2.112±.014	0.542±.008	24.33± .37
20-24	5,405	2.774±.010	2.442±.012	1.057±.007	38.09± .28
25-29	6,539	3.744±.014	3.398±.018	1.718±.010	45.89± .32
30-34	6,182	4.865±.020	4.456±.025	2.357±.014	48.46± .36
35-39	5,558	6.217±.027	5.909±.034	2.956±.019	47.55± .37
40-44	2,536	7.748±.046	7.635±.058	3.437±.032	44.36± .49
45-49	315	8.894±.145	9.150±.181	3.802±.102	42.32±1.33

After mid-age 17.5 years in the case of the colored mothers, and 22.5 years in the case of the white mothers, the percentages of actual to ideal mean parities increase steadily, until they reach high points at about 70 percent in the case of the colored at mid-age 42.5 years, and of about 60 percent in the whites at mid-age 47.5.

Now it is evident that one reason at least why the observed parity means are below the ideal after the starting age-class 10-14 years is because the intrusion of primiparae — women just starting their reproductive life — will tend to lower the parity mean in each age class, and

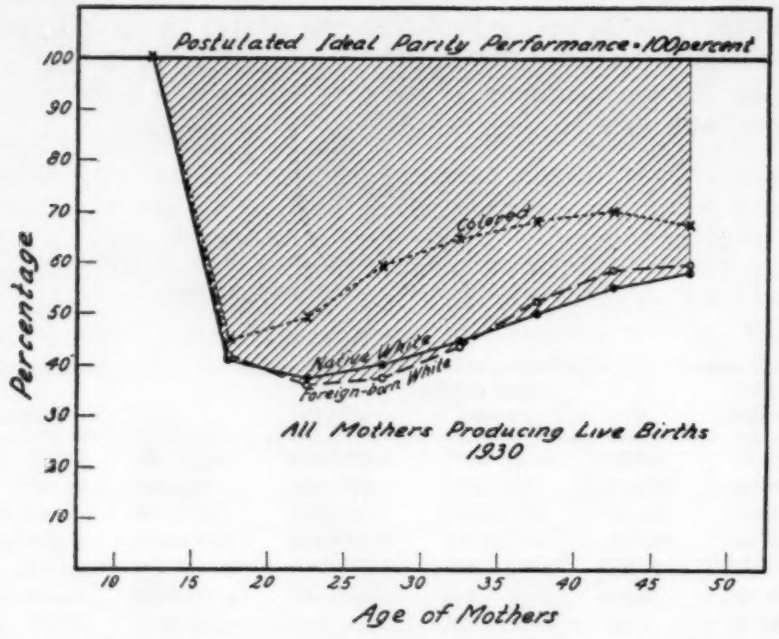

FIG. 5. RELATION TO POSTULATED IDEAL MEAN PARITIES OF THE ACTUAL MEAN PARITIES OF WOMEN PRODUCING LIVE BIRTHS IN 1930. DATA FROM TABLE 19

somewhat in proportion to the relative frequency of these "first birth" women in the class. What is the actual quantitative effect of this factor?

In order to answer this question it was first necessary to construct tables for *multiparae* (women producing their second or higher order birth) corresponding to Tables 15-17 for all *mothers*. As there have

been available no biometric data regarding the parity relations of multiparae as a separate class, and as we shall wish to use these data in a number of ways, they are set forth here as Tables 20-22 inclusive.

These Tables 20-22 for parities of multiparae exhibit in general the same characteristics as Tables 15-17 for parities of all mothers together, with, of course, the differences consequent upon the fact that they contain no first births. The mean parities for multiparae in the 15-19 year age class fall between two and two and a quarter births, and thereafter ascend from that base with advancing age along curves similar in form to those already seen for all mothers together.

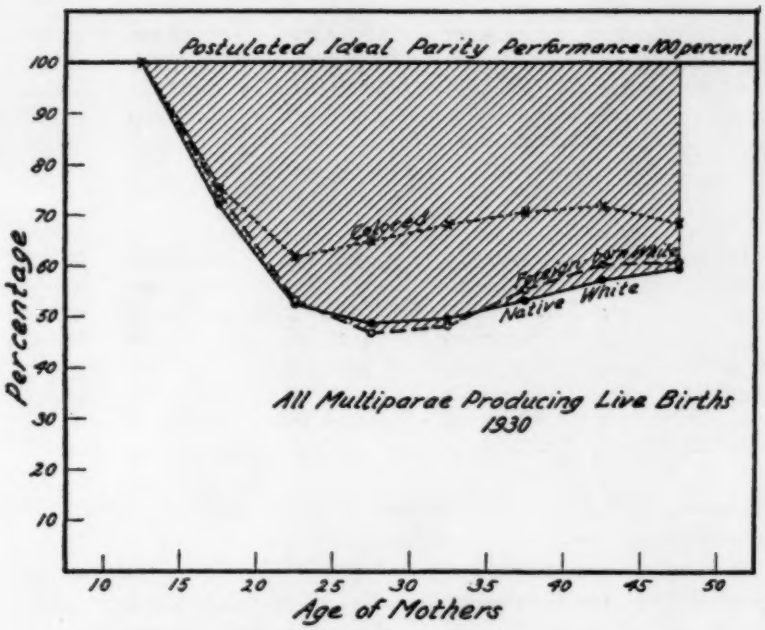

FIG. 6. LIKE FIG. 5, BUT FOR MULTIPARAE ONLY

In order to make clear the rôle played by first births in determining the changes of mean parity with age Table 23 has been prepared. The primary entries in this Table 23 are the differences, group by group and age class by age class, between the *mean* parities of Tables 15-17 and those of Tables 20-22, together with the probable errors of these differences. These absolute differences are then expressed as percentages of

TABLE 21

Biometric constants for variation in parity order of births in 1930 to foreign-born multiparae, by age

A. Live births

AGE (*years*)	*N*	MEAN PARITY ORDER	MEDIAN	ST. DEV.	C. OF V.
15-19	1,682	2.225±.008	2.117±.010	0.503±.006	22.60± .28
20-24	21,811	2.664±.005	2.355±.006	.999±.003	37.51± .14
25-29	45,737	3.280±.005	2.869±.006	1.507±.003	45.95± .12
30-34	47,969	4.350±.007	3.856±.008	2.162±.005	49.69± .13
35-39	39,708	6.075±.010	5.723±.012	2.864±.007	47.14± .14
40-44	15,575	7.824±.018	7.787±.022	3.281±.013	41.93± .19
45-49	1,580	9.109±.061	9.226±.077	3.614±.043	39.67± .55

B. Stillbirths

15-19	39	2.359±.067	2.196±.084	0.620±.047	26.27±2.14
20-24	343	2.913±.044	2.545±.055	1.194±.031	41.01±1.22
25-29	772	3.727±.045	3.250±.057	1.859±.032	49.88±1.05
30-34	1,175	4.937±.051	4.403±.064	2.577±.036	52.19± .90
35-39	1,494	6.735±.054	6.390±.068	3.109±.038	46.17± .68
40-44	843	8.356±.080	8.296±.101	3.456±.057	41.37± .79
45-49	111	9.568±.248	9.154±.311	3.878±.176	40.53±2.12

"all mother" (Tables 15-17) means, in order to indicate their relative magnitudes.

It is seen from Table 23 that the mean parities of multiparae are *significantly* higher than those for all mothers taken together up to age 40 years in all groups, native, foreign-born, and colored; and for the group of mothers producing stillbirths in 1930 as well as for the group producing live births. Furthermore the differences are significant for the native white mothers of live births in 1930 up to age 50 and for the corresponding group of foreign-born white mothers up to age 45.

The magnitude of this first birth effect upon mean parities is greatest in the earlier ages, as would be expected, and diminishes with advancing age of mothers for the obvious reason that the proportion of women having first births diminishes with advancing age.

TABLE 22

Biometric constants for variation in parity order of births in 1930 to colored multiparae, by age

A. Live births

AGE (*years*)	*N*	MEAN PARITY ORDER	MEDIAN	ST. DEV.	C. OF V.
15-19	15,081	2.266±.003	2.133±.004	0.580±.002	25.58± .11
20-24	55,308	3.091±.004	2.826±.004	1.234±.003	39.92± .09
25-29	45,917	4.546±.006	4.315±.008	1.938±.004	42.62± .11
30-34	30,688	6.120±.010	5.976±.012	2.547±.007	41.62± .13
35-39	21,574	7.740±.014	7.703±.018	3.093±.010	39.97± .15
40-44	6,651	9.313±.029	9.385±.036	3.470±.020	37.26± .25
45-49	1,019	10.265±.080	10.455±.100	3.788±.057	36.91± .62

B. Stillbirths

15-19	1,294	2.395±.014	2.197±.017	0.723±.010	30.21± .44
20-24	3,691	3.328±.016	2.986±.020	1.467±.012	44.08± .41
25-29	2,960	4.929±.028	4.655±.035	2.242±.020	45.47± .47
30-34	2,083	6.616±.043	6.404±.054	2.934±.031	44.35± .55
35-39	1,684	7.996±.056	7.915±.070	3.419±.040	42.76± .58
40-44	608	9.919±.098	10.078±.123	3.584±.069	36.13± .78
45-49	114	11.298±.239	11.567±.299	3.783±.169	33.49±1.66

The effect of this first-birth factor in lowering the mean parities of all mothers is much more marked in the white than in the colored mothers, taken as groups. This is plainly connected with the tendency of the colored women to begin breeding early and to keep at it — in other words to a greater inherent tendency to multiparity among the colored, which in turn is in part an expression of the smaller amount and lower efficiency of contraception among the colored as compared with the whites.

With the data now at hand in Tables 20-22 let us proceed to construct another diagram corresponding to Fig. 5, but with the effect of primiparity on parity means eliminated by confining the picture solely to multiparae. For convenience of comparison these two diagrams are placed on facing pages.

The area cross-hatched in Fig. 6 represents the aggregate failure of mothers of live births in 1930 to keep pace in their mean parities at ages with a reasonable (in the sense of not making individually im-

TABLE 23

Differences in mean parity between (a) all mothers as given in Tables 15-17, and (b) multiparous mothers as given in Tables 20-22. These differences show the statistical consequences of primiparity as it is involved in total population parity averages

A. Live births

AGE (*years*)	NATIVE WHITES		FOREIGN-BORN WHITES		COLORED	
	Absolute difference	Percentage difference	Absolute difference	Percentage difference	Absolute difference	Percentage difference
15-19	0.917±.001	74.0	0.962±.009	76.2	0.918±.004	68.1
20-24	.747±.002	39.8	.849±.006	46.8	.612±.005	24.7
25-29	.587±.003	20.8	.639±.007	24.2	.367±.009	8.8
30-34	.427±.004	10.6	.410±.010	10.4	.268±.014	4.6
35-39	.311±.007	5.6	.268±.014	4.6	.202±.021	2.7
40-44	.236±.014	3.3	.177±.025	2.3	.152± *	1.7
45-49	.216±.051	2.5	.141± *	1.6	.134± *	1.3

B. Stillbirths

15-19	1.020±.012	84.4	1.079±.073	84.3	.972±.016	68.3
20-24	1.017±.012	57.9	1.082±.053	59.1	.765±.022	29.8
25-29	.924±.019	32.8	.961±.060	34.7	.536±.040	12.2
30-34	.773±.028	18.9	.688±.071	16.2	.408±.062	6.6
35-39	.595±.039	10.6	.436±.078	6.9	.400±.081	5.3
40-44	.507±.067	7.0	.245± *	3.0	.459± *	4.9
45-49	.431± *	5.0	.298± *	3.2	.264± *	2.4

* Probable error so large that the difference, being less than 4 P.E., cannot be regarded as significant.

possible physiological demands) postulated ideal parity performance, *after the effects of primiparity on average parity performance have been eliminated*. It is plain that this failure is, in the aggregate, still considerable. Also it is perfectly plain that eliminating the statistical effect of primiparity makes no *practical* difference in mean parity performance after age 25 is passed.

We must turn to other factors in any attempt to find out why these women bearing children in 1930 departed in their mean parity perform-

ance so far from the postulated ideal. It is reasonable *a priori* to suppose that, in a statistical sense, this aggregate failure in reproductivity is the consequence of the intermingled action of at least three important sets of factors:

a. The postponment of marriage to varying extents after the attainment of the physiological ability to reproduce, shortly following menarche.

b. Actual group physiological inability to keep up to the postulated ideal mean parity schedule as age advances, this inability being conceivably due to the interaction of a variety of causes, such as disease, gradually declining ovulation rates, gradual diminution of frequency of coitus, and others that may be conceived.

c. The effective practice of contraception.

It is quite impossible with the data now available to appraise the relative influence of these factors with complete precision or generality. There is, however, no occasion for a completely defeatist attitude. Let us therefore proceed to examine one by one these three major factors in the picture and see what can be done towards getting some sort of rough approximation to their quantitative effect.

First consider *age at marriage*. Unfortunately there are no data available for age at marriage of women for the United States as a whole. However there are available in the as yet unpublished records of the writer's laboratory the distributions of age at marriage for 22,962 white females and 3,569 Negro females, the data being derived from the records collected in our investigation of contraception and fertility.[2] This sample has been shown (in the Third Progress Report cited) to be a very fair random sample of the general population in respect of a number of demographic charateristics so far tested. It is probable that in respect of age at marriage this would also be found true, if it were possible to test the point.

These observed distributions of age at marriage were reduced to relative figures on a 10,000 total base, and it was then determined what the postulated ideal mean parities would be at successive quinquennial ages in a population that postponed its marriages after menarche in the

[2] Pearl, R. Contraception and fertility in 2000 women. HUMAN BIOLOGY, Vol. 4, pp. 363-407, 1932; Contraception and fertility in 4945 married women. *Ibid.*, Vol. 6, pp. 354-401, 1934; Third progress report on a study of family limitation. *Milbank Mem. Fund Quarterly*, Vol. 14, pp. 258-284, 1936.

way that the persons in these actual samples did. Then the observed mean parities at ages exhibited by the mothers of 1930 were compared with these new postulated ideal mean parity performances, now corrected for the postponement of marriage factor. In applying the correction to the postulated ideal figures it was assumed that the cohort of women marrying in *any* 5 year age period would produce an average of 1 live baby in that period, and of 2 in each succeeding five year period, leading to mean parities of 3 in the next age period after marriage, 5 in the next, and so on to and including the age period 40-44, which was the last age period in our data in which marriage occurred followed by pregnancy. This assumption is, of course, an extremely drastic one, in that it implicitly denies any diminution whatever of fertility with advancing age. But we are attempting to analyze one factor at a time, and therefore proceed this way.

TABLE 24

Comparison of observed mean parity performance with a postulated ideal corrected for age at marriage

AGE	ORIG. POST. I	WHITES			COLORED	
		Post. II*	Percent N.W.**	Percent F.W.***	Post. III†	Percent C.††
10-14	1	1.00	100.4	100.0	1.00	100.3
15-19	3	1.07	115.8	118.0	1.19	113.3
20-24	5	2.09	89.9	86.8	2.62	94.6
25-29	7	3.71	76.2	71.2	4.46	93.7
30-34	9	5.59	72.3	70.5	6.42	91.2
35-39	11	7.56	73.2	76.8	8.41	89.6
40-44	13	9.55	75.4	80.1	10.41	88.0
45-49	15	11.55	75.5	77.6	12.41	81.6

* Postulate II, which is the originally postulated ideal mean parity performance with corrections added for age at marriage among whites.

** The percentages which the native white mean live birth parities of Table 15 *supra* are of the Postulate II figures in the preceding column.

*** The percentages which the foreign-born white mean live birth parities of Table 16 *supra* are of the Postulate II figures in the second preceding column.

† Postulate III, which is the originally postulated ideal mean parity performance with corrections added for age at marriage among Negroes.

†† The percentages which the colored mean live birth parities of Table 17 *supra* are of the Postulate III figures in the preceding column.

To summarize for the sake of complete clarity: what is now being done is to assume, as a postulated ideal mean parity performance, that women marry at ages corresponding to the actually recorded marriage ages of substantial samples of American women, produce an average of one birth in the age period in which they were married, and thereafter add two births in each succeeding quinquennium to their mean parity record, right up to the menopause.

The results are shown in Table 24 and Fig. 7.

It is evident at once from a glance at Table 24 and Fig. 7 that roughly something of the order of a half of the reproductive deficiency of the women of 1930 below the postulated ideal performance disappears when corrections are made for the effect upon mean parities of

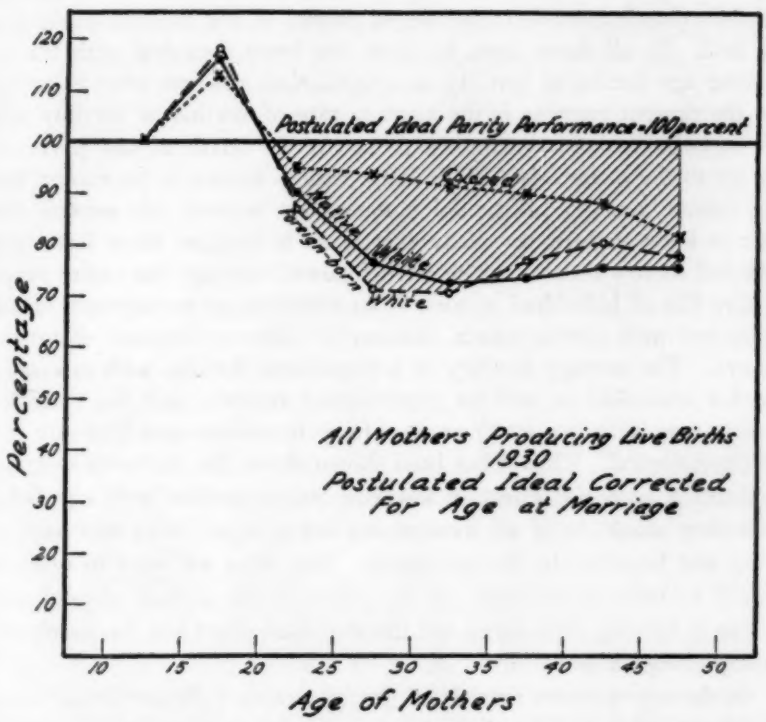

FIG. 7. RELATION OF THE ACTUAL MEAN PARITIES OF WOMEN PRODUCING LIVE BIRTHS IN 1930, TO POSTULATED IDEAL MEAN PARITIES CORRECTED FOR AGE AT MARRIAGE

deferred marriages. In the age period 15-19 the actually observed mean parities, for all the nativity-race(color) groups are even higher than the postulated means.

With a rough approximation to the effect on mean parities of the first factor (age at marriage) in hand, we may turn to a consideration of the second factor, *the natural decline in innate fecundity and fertility with advancing age.* This is a phenomenon falling in the general category of senescence. Its quantitative appraisal in terms of mean parities here under consideration is difficult and uncertain, because of lack of knowledge of the necessary physiological constants. The curves of declining fertility with advancing age to be found in statistical literature are not particularly useful for the present purpose. There are a good many of these, beginning with the pioneer data of Matthews Duncan and their mathematical treatment by Tait, and coming down through Körösi's classic memoir to the recent papers of the Italians working in the field. In all these cases, however, the basic data deal with the advancing age decline of fertility *in a population,* whereas what is wanted for the present purpose is the average rate of decline of fertility with age in individual women known to be overtly fertile at any particular age up to the menopause. This latter rate is known to be slower than the former, and by substantial amount, but beyond this general fact little is known about it. Why this is so is because there have been collected so few records which have followed through the entire reproductive life of individual women from menarche to menopause, uncontaminated with contraception, disease, or other extraneous disturbing factors. The average fertility of a population declines with advancing age for statistical as well as physiological reasons, and the statistical reasons may be as important, or even more important quantitatively than the physiological. Thus it has been shown above that deferred marriage produces a powerful effect in lowering mean parities with age below what they would be if all women married at ages 10-14 and kept on living and breeding to the menopause. But what we want in order to be able to make corrections for the effect of the normal physiological decline in fertility with age is not the statistical effect but the purely and strictly biological one.

In the reproductive records of 30,949 women collected in our study of contraception and fertility already referred to there exists the sort of material necessary to determine the rate of true physiological decline in fertility with age, but up to the present time it has not been possible

to complete its analysis relative to this question. So then the best we can do for the present is to make an approximation from those data.

The nature of the approximation made is as follows. In the first place all the evidence indicates that no significant physiological decline in fertility appears until after the age period 15-19 is past. So then the figures of Postulate II, Table 24, may be allowed to stand for the age classes 10-14 and 15-19. Turning now to the mean and median age specific pregnancy rates for women not practising contraception, married once only, and without gynecological disease, given in Table 7 of our Third Progress Report (*loc. cit. supra*) it appears (1) that to a rough first approximation the decline in fertility with age from the age class

TABLE 25

Comparison of observed mean parity performance with a postulated ideal corrected (a) for age at marriage and (b) for natural decline of fertility with age

AGE	ORIG. POST. I	WHITE			COLORED	
		Post. IV*	Percent N.W.**	Percent F.W.***	Post. V†	Percent C.††
10-14	1	1.00	100.4	100.0	1.00	100.3
15-19	3	1.07	115.8	118.0	1.19	113.3
20-24	5	2.04	92.1	89.0	2.58	96.0
25-29	7	3.53	80.1	74.8	4.34	96.3
30-34	9	5.22	77.4	75.5	6.18	94.7
35-39	11	6.92	80.0	83.9	8.01	94.1
40-44	13	8.59	83.8	89.0	9.79	93.6
45-49	15	10.19	85.5	88.0	11.54	87.8

* Postulate IV, which is the originally postulated ideal mean parity performance with corrections added for (a) age at marriage and (b) natural decline of fertility with age among whites.

** The percentages which the native white live birth parities of Table 15 *supra* are of the Postulated IV figures in the preceding column.

*** The percentages which the foreign-born white mean live birth parities of Table 16 *supra* are of the Postulate IV figures in the second preceding column.

† Postulate V, which is the originally postulated ideal mean parity performance with corrections added for (a) age at marriage and (b) natural decline of fertility with age among Negroes.

†† The percentages which the colored mean live birth parities of Table 17 *supra* are of the Postulate V figures in the preceding column.

period 15-24 through the age period 35-40 and over (averaging the two quinquennial classes in both cases) may be taken as linear in the absence of more precise knowledge of the particular form of the curve if it is in fact not linear; and (2) that the mean rate of this decline is about 3.3 percent per 5 year period in the case of the whites; and (3) by a parallel procedure this mean rate of decline is about 2.1 percent per 5 year period in the case of the Negroes. Corrections to embody these rates of decline are then applied to a population operating as to marriage age in the manner described in connection with the correction for that variable already made above. The resulting theoretical mean parities after the double correction are shown in Table 25 and Fig. 8.

It is evident that after allowance has been made for postponement of marriage and for the decline of innate fertility with advancing age

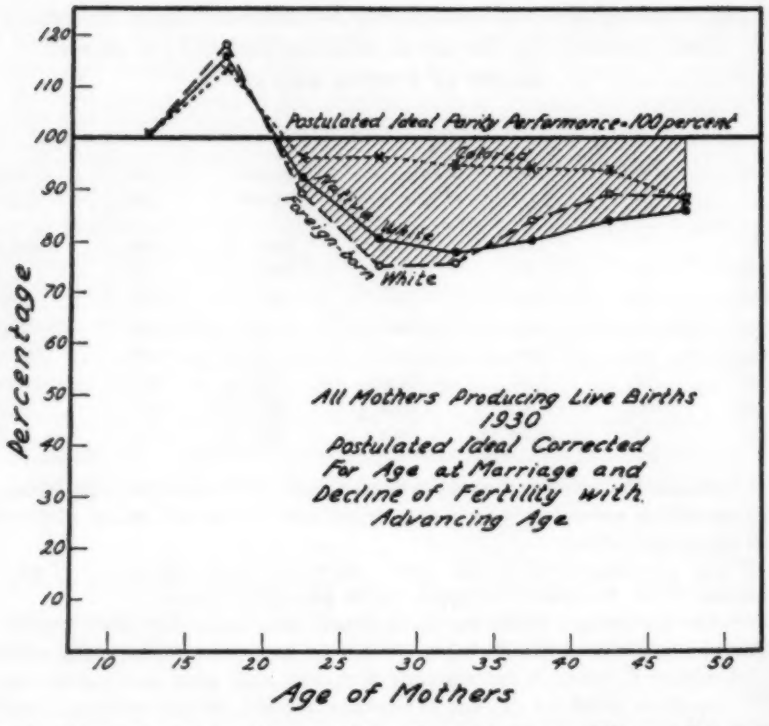

FIG. 8. RELATION OF THE ACTUAL MEAN PARITIES OF THE WOMEN PRODUCING LIVE BIRTHS IN 1930, TO POSTULATED IDEAL MEAN PARITIES CORRECTED FOR AGE AT MARRIAGE AND FOR DECLINE OF NATURAL FERTILITY WITH ADVANCING AGE

there are left only relatively small deficiencies between the actual parity performance of women who bore live children in 1930 in the Birth Registration Area and a theoretical ideal breeding performance that would be not far below the maximal *average* for human populations. We have no sound basis for setting up postulates for the terminal age classes at either end of the reproductive life span, because too many variables are there involved about which adequate quantitative information does not exist. But in the period between the age classes 20-24 and 45-49 inclusive the results seem fairly reasonable approximations.

The differences between the observed and postulated parity performances (with corrections) shown in Table 25 and Fig. 8, are the net residuals left to be accounted for *as resultants of the practice of contraception in the general population* (factor c *supra*), plus whatever other factors not taken into account in making the corrections may be thought to be playing a significant rôle. The only other variable that seems likely to be worth considering quantitatively in this connection is the mortality of women as age advances. Actually corrections have been carried through for this mortality, on the basis of a standard life table, but the resulting changes in the Postulate IV and V mean parities are so small as not to be worth taking the space to present here. They are in fact negligable.

TABLE 26

Theoretical percentage effectiveness of contraception (plus all other factors not taken account of above) in reducing mean parities at ages among women in U.S.B.R.A. producing live births in 1930

Ages	*Native White*	*Foreign-born White*	*Colored*
20-24	7.9	11.0	4.0
25-29	19.9	15.2	3.7
30-34	22.6	24.5	5.3
35-39	20.0	16.1	5.9
40-44	16.2	11.0	6.4
45-49	14.5	12.0	12.2

So then we are led to attribute the residual deficiencies of Table 25 and Fig. 8 chiefly to contraception and present Table 26 to indicate their approximate relative amounts.

It must be clearly understood, and for that reason is re-emphasized that the figures of Table 26, are not to be taken as indicating even ap-

proximately the total effect of contraceptive practices on the national birth-rate. That table concerns only women overtly fertile in 1930, and the effect approximated is that produced by birth control practices upon the mean parity performance of *these women only* over their whole reproductive lives to the date of record and not the effect of birth control on the breeding of all women in the population. Obviously besides these women there exists a presumably large, but at present unknowable, body of women who were prevented from having a baby in 1930 as result of their practice of contraception. If they could be brought into the picture naturally the total effectiveness of contraception would be greater than is indicated in Table 26. How much greater it is impossible to appraise with accuracy. But a very rough and approximate estimate that suggests itself to the writer after weighing all the evidence from the work we have so far done is that the total effectiveness might be of the order of twice the figures of Table 26. But this is only the roughest of estimates and can claim no validity. It is indeed merely a suggestion.

The figures of Table 26, however, suggest with considerable force that contraception as actually practised in the population is not having nearly so great an effect in lowering the reproductivity of those women who from year to year are doing the national breeding as many would have us believe. Birth control appears to be producing its demographic effect mainly in another way. The further we proceed in the study of human fertility, the more evidence there appears to be for the idea that a distinction must be made between two classes of women; namely (a) those who appear as mothers in the annual birth statistics with considerable regularity, and whose total breeding performance once they are married is, as is shown in this paper, not far below a theoretical ideal near the maximum for large population aggregates, and upon whose total breeding performance contraception has had no great effect; and (b) those women who, though married and potentially fertile, appear in the annual birth statistics only once in their reproductive life span, or at most very occasionally, as a result either of their effective practice of birth control or of a low innate fertility or of a combination of both of these causes acting together. All the evidence appears to support the view that the proportion of women in the (b) category is steadily increasing and of those in the (a) category diminishing. It appears to us, subject to a revision of view if more knowledge of the real facts in this complex and difficult field compels it, that it is in the

shifting of the proportions of women in these two categories that birth control propaganda is having its important effect upon the national birth rate, rather that in any evenly distributed lowering of fertility in the breeding population.

The crux of the matter, and next to the proportion of wholly childless marriages the most significant danger signal for population pathology, is the proportion of first births to all births. A considerable proportion of first births are also *only* births. We are indebted to Notestein[3] for the most significant and precise contribution on this point in recent years. He showed that between 1890 and 1910 the percentages of so-called "one-child sterility" in substantial samples of the population *increased* from 13.3 to 19.6 percent in professional class families; from 14.0 to 21.5 percent in his "business" category of occupations; from 13.3 to 17.0 percent in his "skilled" class; from 12.4 to 14.9 percent in his "unskilled" class; and from 8.8 to 10.1 percent in the "farm owner" class. The implications of these figures are plain. Robinson[4] reports for Swarthmore College graduates 12 percent of 236 marriages of men (all ages) excluding widowers, and 16 percent of 227 marriages of women ((all ages) excluding widows, producing only one child. In two French districts Neumann[5] reports percentages of one-child sterility of 24 and 20 respectively. Even where there is no significant voluntary contraception the amount of this one-child sterility can be very considerable, as a result of venereal disease (especially gonorrhea) and other less well understood causes. Külz[6] found among the natives of Yap that of 306 women past the menopause 102, or 33 percent, had been sterile after producing only one child.

VII. LIVE BIRTH AND STILLBIRTH PARITIES

A part of the women delivered of products of pregnancy in 1930 produced live births; another part produced stillbirths. From the point of view of the present study it would have been desirable to combine

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[3] Notestein, F. W. The decrease in size of families from 1890 to 1910. *Milbank Mem. Fund Quart. Bull.*, Vol. 9, pp. 181-188, 1931.

[4] Robinson, Caroline H. Co-educational graduates' birth rates. *Eugen. News*, Vol. 18, pp. 116-118, 1933.

[5] Neumann, J. Über Sterilität. *Wiener med. Wchnschr.*, Bd. 61, pp. 1091 ff. [in 7 parts], 1911.

[6] Külz, L. Ueber das Aussterben der Naturvölker. II. Das Aussterbe-Mechanismus bei den Karolinern der Insel Jap. *Arch. f. Frauenkunde und Eugenik*, Bd. 6, pp. 44-85, 1920.

TABLE 27

Differences (live birth data minus stillbirth data) in the biometric constants for parity between mothers producing respectively live births or stillbirths in 1930, by color, nativity, and age of mother

A. Native white mothers

AGE CLASS (*years*)	MEAN	MEDIAN	S.D.	C. of V.
10-14	+.004±.001	+.002±.002	+.064±.001	+6.4± .09
15-19	+.031±.004	+.028±.005	—.005±.003	—1.4± .79
20-24	+.121±.007	+.256±.008	—.073±.005	—7.9± .36
25-29	+.006±.013	+.131±.016	—.263±.009	—9.5± .45
30-34	—.053±.020	+.007±.025	—.329±.014	—7.3± .48
35-39	—.088±.028	—.116±.035	—.337±.020	—5.1± .46
40-44	—.042±.049	—.052±.062	—.353±.035	—4.6± .59
45-49	+.162±.156	+.038±.196	—.455±.110	—6.1±1.56

B. Foreign-born white mothers

10-14	....	....	....	....
15-19	—.017±.030	+.007±.038	—.064±.021	—4.4±2.05
20-24	—.016±.030	+.095±.038	—.146±.021	—7.4±1.59
25-29	—.125±.039	+.033±.049	—.346±.028	—9.7±1.42
30-34	—.309±.050	—.283±.063	—.474±.035	—6.9±1.14
35-39	—.492±.057	—.563±.071	—.344±.040	—1.4± .80
40-44	—.464±.085	—.458±.107	—.231±.060	— .3± .88
45-49	—.302±.267	+.130±.335	—.397±.189	—3.0±2.41

C. Colored mothers

10-14	+.003±.001	+.002±.001	+.057±.001	+5.7± .07
15-19	—.075±.008	—.028±.010	—.113±.006	—5.4± .49
20-24	—.084±.015	+.038±.019	—.217±.011	—6.6± .56
25-29	—.214±.029	—.151±.037	—.353±.021	—5.6± .60
30-34	—.356±.046	—.303±.058	—.450±.033	—4.6± .66
35-39	—.058±.061	—.069±.076	—.439±.043	—5.4± .69
40-44	—.299±.111	—.524±.139	—.394±.078	—2.9± .97
45-49	—.903±.267	—1.076±.335	—.153±.189	+1.8±1.94

these two groups, since in fertility analysis there is no important biological reason for separating them. The separation of the two classes of mothers in the official birth statistics must not be taken to imply (except in the case of first births) that a woman who has a stillbirth in a particular year has never had anything but stillbirths in the course of her reproductive life. All that is implied is that each woman in the stillbirth category produced a stillbirth in the year of record. What her previous reproductive performance had been the official statistics do not tell us, except insofar as concerns the total number of births experienced.

There is, however, one question not so far discussed that can be answered from the material. That is: Do the biometric constants for variation in parity differ consistently and significantly as between women bearing a live birth in a particular year and those bearing a stillbirth in that year? And if so in what way? Table 27 presents the necessary differences and their probable errors to answer these questions. Entries printed in italics represent the differences that are three or more times their probable errors, and are therefore to be regarded as probably significant statistically.

From the figures of Table 27 the following inferences may be fairly drawn:

1. There is a small but definite tendency for the mean parities to be *higher* in the mothers bearing stillbirths than in those bearing live births. Thus, of the 23 differences in means 17 are minus in sign (mothers of stillbirths of higher mean parity), and of these 17 minus differences 10 are more than three times the probable error.

2. Of the 23 differences in medians 11 are minus and of these 11 there are 8 that are three or more times the probable error. Thus the tendency shown by the means is in a measure reflected in the medians but not strongly.

3. The mothers bearing stillbirths in 1930 are definitely more variable than those bearing live births in respect of parity, whether judged by standard deviations or coefficients of variation. Of the 23 differences in standard deviation 21 are minus, and 18 of these 21 are three or more times the probable error. Of the 23 differences in coefficients of variation 20 are minus in sign, and 15 of them are three or more times the probable error.

It seems probable that a part of the explanation of these trends may be connected with the likelihood that prior stillbirths that have occurred before a given parturition will generally in part be forgotten and there-

fore not get recorded on the birth certificate of a particular year, whereas if the birth of a particular year is itself a stillbirth it generally cannot escape being recorded. The result would be a tendency for the mothers of stillbirths in a given year to show somewhat higher mean parities, and greater variability in parity. Another part of the explanation may be that in general the women of higher fertility are the ones most likely on the average to have a stillbirth resulting from any particular pregnancy, because of the well-known increase in the abortion rate with higher parities.[7]

VIII. DISCUSSION AND SUMMARY

In this paper an attempt has been made to show quite clearly, for the first time so far as we are aware, the significance of an analysis of the parity relations of mothers bearing children in any year to the study of the problems of fertility and contraception primarily, and of the problem of population generally. The results indicate that there is still a great deal of pertinent and significant information to be extracted from official birth statistics for a general population, if their implications are more thoroughly explored and penetrated than has been the usual practice. The present paper by no means exhausts the useful possibilities of parity analysis. Indeed it is only a beginning. We expect to publish further studies in the same direction as opportunity offers.

It has been shown that in the United States in 1930 from a quarter to more than a third of all births, depending on the group of mothers concerned, were *first births* (Table 1, p. 67). This is a high proportion — definitely higher than would be found in a population reproducing as a whole more actively and adequately than ours is at the present time.

It is of some interest to compare these figures with more or less similar data from the literature. In a study of 1108 pregnant women who attended the Stockport (England) antenatal clinics, taken without "selection of cases as to social circumstances or as to parity" Reid and Mackintosh[8] present figures from which we calculate that 39.7 percent of the pregnancies, taking all ages of mothers together, were of parity I. This is substantially the same as the 40.15 ± .15 percent for the native

[7] Cf. Pearl, R. Biological factors in fertility. *Annals Amer. Acad. Pol. and Soc. Sci.*, Vol. 188, pp. 14-25, 1936.

[8] Reid, W. J. S., and Jean M. Mackintosh. Incidence of anaemia in pregnancy. Influence of social circumstances and other factors. *Lancet*, Vol. 232, pp. 43-45, 1937.

white mothers of the present study bearing stillbirths in 1930. On the other hand Sundin,[9] in a study of 335 women in his private practice in Lund (Sweden), records data showing 25.5 percent as of parity I, a figure falling between the 24.34 ± .06 percent for our foreign-born white mothers of live births, and the 28.98 ± .06 percent for our colored mothers of live births. An analysis of the data in Kennedy's[10] very careful and thorough study of Edinburgh (Scotland) hospital records makes it possible to set up the following more detailed comparison of percentages of first parities to all parities:

Age class	*U.S.B.R.A. Total whites, 1930, live births*	*Edinburgh Hospital records (Kennedy)*
Under 25	55.5	63.8
25-34	19.7	28.8
35-44	5.5	18.8
45 and over	2.6	9.9

These figures suggest that the higher Edinburgh percentages probably reflect in part the selective tendency for women to have their first births in hospitals, in a higher proportion of cases than in subsequent parities. This tendency is well known. In the first 1000 confinements in the then newly opened Sloane Maternity Hospital in New York, McLane[11] reported that 54.7 percent were first pregnancies This is much higher than any of the percentages of primiparae (all ages together) shown in Table 1 *supra*. It is of interest to note that Peckham[12] in 1936, or 45 years later, reported that 54.7 percent of the general obstetric clinic population of the Johns Hopkins Hospital were primigravidae.

Two other, and somewhat extreme, examples may be given to illustrate the fact that *selection* of groups of women relative to a wide variety of conditions and circumstances may alter widely the proportionate amount of primiparity observed in the group away from general

[9] Sundin, O. Zur Frage von der Menstruation während des Stillens. *Zentralbl. f. Gynäk.*, Bd. 33, pp. 242-245, 1909.

[10] Kennedy, W. The menarche and menstrual type: Notes on 10,000 case records. *Brit. Jour. Obst. and Gynec.*, Vol. 40, pp. 792-804, 1933.

[11] McLane, J. W. The Sloane Maternity Hospital. Report on the first series of one thousand successive confinements from January 1st, 1888, to October 1st, 1890. *Amer. Jour. Obst.*, Vol. 24, pp. 385-418, 1891.

[12] Peckham, C. H. Abortion. A statistical analysis of 2287 cases. *Surg. Gyn., and Obst.*, Vol. 63, pp. 109-115, 1936.

population figures of the sort appearing in our Table 1 *supra*. The first example illustrates how pathological factors may be related to parity distributions. It has already been seen from Table 1 (p. 67) that the percentages of I-para women are generally, for all groups and practically all age classes higher among the mothers producing stillbirths than among those producing live births. Difficulties and disturbances of pregnancy generally occur more frequently in proportion among primiparae than among multiparae. Greenhill[13] reported that of 78 cases of eclampsia occurring among 29,587 obstetric patients 73.1 percent were primiparae. A wholly different sort of selection is involved in and implied by the processes that assemble together as a statistical group the clientele of a birth control clinic. Robishaw[14] reports that of 4,000 women admitted to the Maternal Health Clinic of Cleveland, Ohio, 3,616 had been pregnant one or more times when admitted. Of these 3,616 women 491 or 13.6 percent had been pregnant once only.

A comparative discussion of *patterns of reproductivity* starts from the idea that the normal primitive pattern of reproduction in mammals implies (a) that the mean age of mothers of first births would be only a little above the mean age at puberty or menarche (taken as the beginning of the physiological possibility of reproducing by the female); (b) that the amount of variation in mothers in age at first birth would be small; (c) that the variation in age of women at births of all parities taken together should be of generally the same order of magnitude as variation in total duration of menstrual life (the span of reproductive capacity). Quantitative appraisal of actual performance in relation to each of these three points showed that the women in the U. S. Birth Registration Area bearing children in 1930 exhibited a pattern of reproductivity widely divergent from that of mammals lower in the evolutionary scale, in all respects tested. The divergences were greatest in the performance of primiparae. Among the nativity-race(color) groups the colored came closest to the infra-human mammalian pattern, so far as concerns primiparae, and on the whole farthest from it in the one respect in which the behavior of women of all parities was tested.

Adequate reproductivity is discussed on the basis that if a woman produces in any given year her fourth living child (or a child of parity

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[13] Greenhill, J. P. Eclampsia at the Chicago Lying-in Hospital. *Jour. Amer. Med. Assoc.*, Vol. 87, pp. 228-232, 1926.

[14] Robishaw, Ruth A. A study of 4000 patients admitted for contraceptive advice and treatment. *Amer. Jour. Obst. and Gynec.*, Vol. 31, pp. 426-434, 1936.

order higher than IV) she may fairly be regarded as having demonstrated that she has adequately reproduced. The most striking result that emerges from the analysis of the data on this point of view (Table 9) is found in the age and nativity-race(color) differentials. While only just under 8 percent of the white women *producing live births in 1930 in U.S.B.R.A.* in the age group 20-24 years were having their fourth or higher parity live birth nearly 21 percent of the colored ones were so doing. In the next higher age class (25-29 years) just slightly under 60 percent of the colored women had completed their proof of adequate reproductivity, as against about half as many relatively among the white women. Over three-quarters of the colored women aged 30-34 years were quadriparous or better, as against only a little more than half the white women in the same age class. In every age period of reproductive life the percentage of IV- and higher-parous women is greater among the colored than among the white. The adequate reproductivity curves of the native and foreign-born white women do not differ markedly from each other throughout their courses.

In order to give some idea of the comparative significance of the present day performance of American women overtly fertile in a particular year in respect of this matter of adequate reproductivity Table 28 is presented. It is not exhaustive, and is not intended to be. Lack of space compels a selection from the voluminous material available. The entries have been chosen with the primary idea of giving some indication of the range of variation in this respect exhibited by different racial, social, economic and pathologic groups of human beings, as well as some indication of how great has been the secular change during the last century. It is to be understood that in computing the percentages of adequate reproductivity from data in the literature all physiologically sterile and wholly childless matings have been excluded, because that is the situation relative to the U.S.B.R.A. mothers of births in 1930. The designations *Rep. Inc.* or *Rep. Fin.*, appearing in connection with each item in the table have the following significance: *Rep. Inc.* means that the total aggregate reproductivity of the group as a whole had not been completely finished at the time of record, because not all the women had passed the menopause; *Rep. Fin.* means that the total aggregate reproductivity of the group had been completed at the time of record because all the women had passed the menopause. The items in the table are arranged in descending order of percentages of adequate re-

TABLE 28

Percentages of adequate reproducers (mothers IV-para and higher) in various groups

DATE	PLACE AND GROUP	*N*	PERCENT ADEQUATE REPRODUCERS	SOURCE
1933	Samarkand. Tajik women. Rep. Fin.	33	97.0	Gagejewa-Wischnewskaja[15]
1886	Russia. Peasants. Husband lives at home. Rep. Fin. (presumably)	522	95.6	Zhbankoff[16]
1929	Massachusetts. Foreign-born mothers of mentally defective children. "Unknown" omitted. Rep. Fin.	783	92.1	Dayton.[17] Table 7
1933	Samarkand. Usbeg women. Rep. Fin.	37	91.9	Gagajewa-Wischnewskaja[15]
Marriages before				
1875	Gablenberg near Stuttgart. Rep Fin.	515	87.6	Weinberg[18]
1904-1907	Berlin. Working class women. Rep. Fin.	374	87.2	Hamburger[19]
1929	Massachusetts. Native born mothers of mentally defective children. "Unknown" omitted. Rep. Fin.	187	80.2	Dayton.[17] Table 7
1886	Russia. Peasants. Husband goes to town to earn living. Rep. Fin. (presumably)	521	78.7	Zhbankoff[16]
1926	New York State. Families of delinquent boys in 3 reformatory institutions. Rep. Inc. (probably in some degree but not much)	1,522	76.7	Slawson.[20] Table 75
Before				
1800	Hyde, Waldo, and Stone genealogies. Rep. Fin.	....	71.1	Wilson and Hilferty.[21] Table IV
1926	West Riding of Yorkshire. Families of miners. Children 11-13 years old. Rep. Inc.	1,106	69.1	Sutherland[22]
1926	München. Mothers of 725 feeble-minded children in special schools. Rep. Inc.	650	66.6	Prokein[23]

TABLE 28 *(continued)*

DATE	PLACE AND GROUP	*N*	PERCENT ADEQUATE REPRODUCERS	SOURCE
1898-1902	New Hampshire births to foreign-born mothers. Rep. Inc.	18,818	48.9	Young.[34] Table X
1904-1907	Berlin. Wealthy women. Rep. Fin.	66	47.0	Hamburger[19]
1936	Cleveland, O. Clients of Maternal Health Clinic. Rep. Inc.	3,536	44.3	Robishaw.[14] Table 1
1929	Connecticut rural families. Rep. Fin.	507	43.8	Whetten.[35] Table 1
1933	Tsinan, China. Cheeloo Hospital Pediatric Service. Live births. Rep. Inc.	2,500	41.1	Fan.[20] Table 1
1930	*U.S.B.R.A. Foreign-born white. Live births. Rep. Inc.*	*230,103*	*40.4*	This paper. Table 9
1930	*U.S.B.R.A. Colored. Live births. Rep. Inc.*	*248,212*	*40.3*	This paper. Table 9
1929	Connecticut, native born, Protestant farm women. Rep. Fin.	144	31.9	Whetten.[35] Table IV
1931	Kurashiki, Japan. Textile workers. Rep. Inc.	1,010	31.3	Teruoka.[37] Table 7
1898-1902	New Hampshire births to native mothers. Rep. Inc.	21,405	30.1	Young.[34] Table X
1890-1922	French and Belgian ducal families. Rep. Inc.	95	29.5	Savorgnan[29]
1930	*U.S.B.R.A. Native white. Live births. Rep. Inc.*	*1,578,856*	*29.3*	This paper. Table 9
1920-1933	New York State exclusive of New York City. Native white mothers. Rep. Fin.	....	27.9	Wilson and Hilferty.[21] Table IV
1890-1923	English, Scottish, and Irish nobility. Rep. Inc.	90	26.7	Savorgnan[29]
1930	"A good New England university". Faculty members. Rep Fin. (practically)	27	18.5	Willoughby[30]

[15] Gagajewa-Wischnewskaja, H. M. Zur Rassenphysiologie des Geschlechtslebens derTadschikinnen und Usbekinnen Samarkands. *Zeitschr. f. Rassenphysiol.*, Bd. 6, pp. 180-192, 1933.

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[17] Dayton, N. A. Intelligence and size of family. Survey of 10,455 retarded children in the public schools of Massachusetts. *Jour. Hered.*, Vol. 20, pp. 365-374, 1929.

[18] Weinberg, W. Das mathematische Prinzip der scheinbaren Überfruchtbarkeit der Eltern ausgelesener Kinder und der Nachwuchs der Begabten. *Ztschr. f. soziale Med.*, Bd. 4, pp. 178-185, 1909.

[19] Hamburger, C. Über den Zusammenhang zwischen Konceptionsziffer und Kindersterblichkeit in grossstädtischen Arbeiterkreisen. *Ztschr. f. soziale Med.*, Bd. 3, pp. 121-143, 1908.

[20] Slawson, J. The Delinquent Boy: a Socio-psychological Study. *Boston* (Badger) 1926 ca. Pp. viii + 477.

[21] Wilson, E. B., and M. M. Hilferty. Size of completed families. *Jour. Amer. Stat. Assoc.*, (Sept. Suppl.), Vol. 30, pp. 577-580, 1935.

[22] Sutherland, H. E. G. Relation of IQ to size of family. *Jour. Educ. Psychol.*, Vol. 20, pp. 81-90, 1929.

[23] Prokein, F. Ueber die Eltern der schwachsinnigen Hilfsschulkinder Münchens und ihre Fortpflanzung. *Arch. f. Rass.-u. Gesellschaftsbiol.*, Bd. 17, pp. 360-370, 1926.

[24] Young, A. A. The birth-rate in New Hampshire. *Publ. Amer. Stat. Assoc.*, Vol. 9, pp. 263-281, 1905.

[25] Whetten, N. L. Education and size of family. *Jour. Hered.*, Vol. 24, pp. 275-278, 1933.

[26] Fan, P. L. Chinese infants and children. A study of the infant and child mortality, size of family, and sex ratio, on 2500 cases. *Chinese Med. Jour.*, Vol. 47, pp. 652-661, 1933.

[27] Teruoka, G. Über die Fruchtbarkeit der Ehefrauen der Arbeiterklasse. *Arch. f. Frauenk.*, Bd. 17, pp. 47-60, 1931.

[28] Savorgnan, F. La fecondita della aristocrazie. II. Le case ducali della Francia e del Belgio. *Metron*, T. 4, pp. 558-575, 1925.

[29] Savorgnan, F. La fecondita della aristocrazie. III. Le case ducali d'Inghilterra, Scozia e Irlanda. *Ibid.*, T. 5, pp. 69-88, 1925.

[30] Willoughby, R. R. The dying professor. A study in faculty family size. *Jour. Hered.*, Vol. 21, p. 273, 1930.

producers. The dates given in the first column of the table refer as nearly as possible to the period in which the group reproductive performance occurred. The indications here are in some cases rather rough, the date of publication of the paper cited being the only specific time record to be had in such cases.

It is obvious that all of the items of Table 28 are not strictly comparable with each other. Of the 27 items in the table 14 are in the Rep. Fin. category and 13 in the Rep. Inc. category. This makes, of course, a real difference. The average (unweighted) percentage of adequate reproducers for the Rep. Fin. items is 67.9, as against 44.2 for the Rep. Inc. It will therefore be well not to make comparisons across this barrier. But the significant point that does appear from this table, incomplete and fragmentary as it is, is found by comparison of the sorts of folk that make up the end items in both categories. In the Rep. Fin. category the four groups with the *highest* percentages of adequate reproducers (items 1-4 inclusive) are respectively Tajik women, Russian peasants, foreign-born mothers of mentally defective children, and Usbeg women; in short either relatively uncivilized people in a low state of culture or people genetically defective. On the other hand the four Rep. Fin. groups with the *lowest* percentages of adequate reproducers (items 16, 20, 25, 27) are Connecticut rural families, Connecticut native-born Protestant farm women, native-born up-state New York women, and university professors' wives; in short the sort of people often called "the salt of the earth". The Rep. Inc. category tells the same kind of story. The four items there with the *highest* percentages of adequate reproducers (items 9, 11, 12, 13) are respectively mothers of delinquent boys in institutions, wives of Yorkshire miners, mothers of feeble-minded children, and the foreign-born in New Hampshire about 40 years ago; again perhaps not the most desirable sorts of people conceivable in a social point of view. On the other hand the four groups in the Rep. Inc. category with *lowest* percentages of adequate reproducers (items 22, 23, 24, 26) are respectively native-born New Hampshire women, French and Belgian noble families, native white U.S.B.R.A. mothers of 1930, and English, Scottish, and Irish noble families. In sum, we arrive once more at the familiar social class differential fertility stopping place, though the approach has been along a somewhat different route.

An analysis of *parity order by age of mother* leads to the tentative conclusion (Table 26) that the effect of contraception as actually prac-

tised in the population is not having nearly as great an effect in lowering the reproductivity of those women who from year to year are doing the national breeding as many would have us believe. Other factors, and notably deferred marriage, play extremely important rôles. Furthermore there appears to be some probability that birth control as actually practised acts rather more importantly in a quantitative sense in keeping women out of the category of breeders at all or admitting them into that category only once in a lifetime, than it does relative to the "proper spacing of pregnancies" planned by multiparae.

Finally it appears upon comparing the *parities of women producing live births and those producing stillbirths* in a particular year that the mean and median parities of the latter group tend to be a little higher than those of the former group. Also the latter group is more variable in its parity distribution than the former.

ON THE WEIGHT OF THE PARATHYROIDS[1]

BY RAYMOND PEARL

IN A study of the endocrine organ weights in the mentally diseased[2] the comparison of the biometric constants for parathyroid weights in the insane with a "normal" (non-insane) sample encountered a curious difficulty. This was that in the description of the longest and best series of so-called "normal" parathyroid weights then available — that of Danisch[3] — there could be found no precise and unequivocal statement as to whether that author had weighed all four parathyroids (upper and lower, right and left) in each of his subjects to arrive at total parathyroid weight, or had weighed only the two from one side of the body. Consequently it was impossible to be sure exactly what his averages really meant. The presumption from the internal evidence of his papers seemed to the writer clearly to be that he had weighed all four, and that the averages given were of the summed weight, because in his second paper on definitely diseased parathyroids he gave detailed figures separately for each of the four glands in each subject as well as sums. Furthermore Roessle and Roulet[4] in their book obviously accepted Danisch's figures as total parathyroid weights, nowhere intimating that they were giving half organ weights for the parathyroids and whole organ weights for all the other organs discussed. Freeman,[5] however, in the first publication to appear regarding the work of this Department on endocrine organ

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[1] From the Department of Biology of the School of Hygiene and Public Health, Johns Hopkins University, Baltimore, Maryland.

[2] Pearl, R., M. Gooch, and W. Freeman. A biometric study of the endocrine organs in relation to mental disease. HUMAN BIOLOGY, Vol. 7, pp. 350-391; 555-607, 1935.

[3] Danisch, F. Die menschlichen Epithelkörperchen im Senium. I. Mitth. *Frankf. Ztschr. f. Path.*, Bd. 30, pp. 443-462, 1924.

[4] Roessle, R., and F. Roulet. Mass und Zahl in der Pathologie. *Berlin* (Springer), 1932.

[5] Freeman, W. The weight of the endocrine glands. HUMAN BIOLOGY, Vol. 6, pp. 489-523, 1934.

weights, concluded that Danisch's figures were for half parathyroid weights only, apparently only for the reason that our means for total weight of parathyroid tissue from the mentally diseased material were roughly twice the magnitude of Danisch's for normals. The attempt was made to get at the truth of the matter by correspondence with Danisch, but without success. No reply was received. The whole dilemma was discussed at length in our paper (*loc. cit.*, pp. 558-560), but we were unable to resolve it satisfactorily, and so resorted to treating the data throughout the remainder of the discussion separately on the alternative hypotheses that Danisch's figures represented either (a) half or (b) whole parathyroid weights.

Fortunately some further light can now be thrown upon the matter, thanks to an important recent paper by Maingard.[6] In that paper are given frequency distributions of the lengths, breadths, thicknesses, and weights of all the parathyroid glands found at autopsies of 45 Europeans and 39 Bantus in the Johnnesburg Hospital. The total numbers of separate individual glands according to the different distributions as given in the paper are:

	European	*Bantu*
Length	151	133
Breadth	151	133
Thickness	142	130
Weight	148	140

From these figures one concludes that the 45 European cadavers yielded in total 151 separate individual parathyroid glands, or an average of 3.36 per person autopsied; while the 39 Bantu cadavers yielded 140, or an average of 3.59 per person, or roughly a quarter of a gland more per person on the average. However the manuscript data furnished me by Dr. Maingard for 37 Europeans and 36 Bantus for which in each case total weight of parathyroid tissue was determined give 132 separate glands for the Europeans, or 3.57 per individual on the average, and 130

[6]Maingard, J. F. The anatomy of the European and Bantu parathyroid glands. *South African Jour. Med. Sci.*, Vol. 1, pp. 91-96, 1935. It gives me great pleasure to extend my warmest thanks to Dr. Maingard for his kindness in giving me further details, in correspondence, regarding his technique, and finally for furnishing me a detailed manuscript copy of all his data for which he had total parathyroid weights.

for the Bantus, or an average of 3.61 per person. Heinbach[7] states 3.2 as the average number of glands per cadaver, based on 25 autopsied persons. His own data however show that this average is incorrect, the average from a total of 86 glands in 25 persons being evidently 3.44. This also is the mean that one gets from the distribution that he gives on p. 253.

Table 1 sets forth the principal biometric constants that we have derived from Maingard's weight distributions as given in the paper cited. Sheppard's correction for the second moment was used, the class units of the distributions being 10 mgm.

TABLE 1

Biometric constants for weight of single individual parathyroid glands in Europeans and Bantus derived from the original data of Maingard, 1935

Constant	*European*	*Bantu*
Mean (mgm.)	64.39±3.84	59.29±3.21
Median (mgm.)	40.65±4.82	35.56±4.02
Standard deviation (mgm.)	69.30±2.72	56.33±2.27
Coefficient of Variation (%)	107.63±7.68	95.02±6.42

From the data at hand certain points may be noted. In the first place it will be well to set down Danisch's averages for comparison.

"Normal" parathyroid weights (compiled from data of Danisch)

AGE GROUP *(years)*	CASES	WEIGHT OF PARATHYROIDS *(mgm.)*
21-30	8	63
31-40	9	66
41-50	15	71
51-60	10	68
Unweighted means	42	67
60-70	..	..
71-80	30	70
80 and over	..	..

[7] Heinbach, W. F., Jr. A study of the number and location of the parathyroid glands in man. *Anat. Rec.*, Vol. 57, pp. 251-257, 1933.

If these average weights are compared with those of Table 1 it seems impossible not to conclude that Danisch's averages really related, *not* to half the total parathyroid tissue in the body (as Freeman concluded), and *not* to all the parathyroid tissue in the body (as I concluded), *but to the average weights of separate, single individual parathyroid glands.*

The next point to be noted is that Maingard's data for single glands exhibit a much greater variability, as measured by the coefficient variability, than do ours (Pearl *et al., loc. cit.* Table 24, p. 556) for total parathyroid tissue per cadaver. This is precisely the result that would be expected *a priori,* for the same kind of reason that leg length and sitting height — components of stature — are each more variable relatively than total stature.

The South African distributions are markedly skew as shown by the differences between means and medians, and in the same direction as the weight distributions from our material here. But relatively the skewness is greater for the single glands (Maingard's data) than for the sum of all the glands per cadaver (our data), which again would be expected *a priori.*

It has been shown above that the average number of separate parathyroid glands (per individual autopsied) found by Maingard was 3.57 for Europeans, and 3.61 for Bantus. If the mean (or median) weights of Table 1 are multiplied by these number means for the respective racial groups, there will result the following figures:

	European	*Bantu*
"False" mean total parathyroid weight (mgm.)	229.87	214.04
"False" median total parathyroid weight (mgm.)	145.12	128.37

These total figures are designated as "false" for the obvious reason that they take no account of any inter-correlations that may (and probably do) exist between the weights of the several separate individual parathyroid glands in the same individual. What is needed in order to reach an accurate mean weight of total parathyroid tissue in the body, and the degree of inter-individual variation about this mean, is a distribution that will show the frequency distribution of Maingard's Europeans, for example, in respect of total parathyroid weight, *i.e.* the summed weight of all separate parathyroid glands found in each individual. Such a figure for individual *A,* for example, might be $50 + 40 + 40 + 40 = 170$ mgm., while for another individual *B,* it might be $62 + 55 + 95 = 212$ mgm., *A* being possessed of four and *B* of only three separate parathyroid glands.

TABLE 2

Frequency distributions for weight of total parathyroid glands per cadaver (Maingard's data)

Weight (mgm.)	*European*	*Bantu*	*Weight (mgm.)*	*European*	*Bantu*
0-49	..	1	500-549	..	2
50-99	3	3	550-599	..	2
100-149	10	7	600-649	..	..
150-199	6	7	650-699	..	..
200-249	9	5	700-749	..	..
250-299	2	..	750-799	1	..
300-349	2	4	800-849	..	..
350-399	..	1	850-899	1	..
400-449	..	2	900-949	1	..
450-499	2	2	Totals	37	36

Through the kindness of Dr. Maingard, it is now possible to present here these desired data. The distributions are given in Table 2.

From the distributions of Table 2 it is evident that three of the Europeans presented total parathyroid weights far outside the usual range. It is not unreasonable to assume that the parathyroids in these three cases are abnormal, for pathological or other reasons. In any case it seems best to calculate the biometric constants for the Europeans both with these three aberrant individuals included and without them.

The biometric constants derived from Table 2 are presented in Table 3.

TABLE 3

Biometric constants for weight of all parathyroid glands (total parathyroid weight per cadaver) in Europeans and Bantus, derived from the distributions of Table 2

Constant	*European*	*Bantu*
Mean (mgm.), all individuals included.....	250.68±22.44	254.17±17.27
Mean (mgm.), 3 aberrant Europeans omitted....	197.06±10.85	....
Median (mgm.), all individuals included.....	195.83±28.13	200.00±21.64
Median (mgm.), 3 aberrant Europeans omitted	183.33±13.59	....
Standard deviation (mgm.), all individuals included	202.38±15.87	153.60±12.21
Standard deviation (mgm.), 3 aberrant Europeans omitted	93.76± 7.67	....
Coeff. of Var. (%), all individuals included....	80.73± 9.60	60.43± 6.32
Coeff. of Var. (%), 3 aberrant Europeans omitted	47.58± 4.69	....

From the data of Table 3 it seems reasonable to conclude that probably the average absolute weight of the total parathyroid tissue per cadaver is normally not widely different in Bantus from what it is in Europeans but may possibly be a little greater. The data suggest that perhaps the Bantus may be normally more variable, both absolutely and relatively in total absolute weight of parathyroid tissue than the Europeans. It seems probable that the European values with the three aberrant individuals omitted from the computations should be regarded as more nearly representative of normal values for Europeans in general than are the constants derived from the whole European series as given.

It is interesting to note that the actual mean and median total parathyroid weights in Table 3 are throughout consistently *higher* than the computed "false" total weights discussed above, provided all individuals be included, as they are on both sides of the comparison. This indicates an assortative association or correlation of the individual glands with each other in respect of weight.[8]

A comparison of the constants of Table 3 for Europeans with those given by Pearl, Gooch, and Freeman (*loc. cit.*, p. 556) for white males, and of the values for Bantus with those for Negro males, makes it clear that the mean and median values for the psychiatric patients are *lower* than those derived from Maingard's data. On the other hand, the data of Gilmour and Martin[8] suggest that the question cannot be regarded as settled by Maingard's European data. There is still the possibility that our tentative conclusion may have been substantially correct that psychiatric patients tend to have heavier parathyroids than normals.

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[8] Just as the proof sheets of the present paper were being read there came to hand the important paper by J. R. Gilmour and W. J. Martin on "The weight of the parathyroid glands" (*Jour. Path. and Bact.*, Vol. 44, pp. 431-462, 1937). This is clearly the most thorough investigation of the subject yet made. There has not as yet been opportunity to compare in detail the results of Gilmour and Martin with our earlier data on the insane or with Maingard's data here discussed. But in general it appears that so far as concerns adult white males the mean total parathyroid weights for our insane material are generally higher by probably significant amounts than those of the English series. For white females there is a suggestion of the same relationship but the differences are smaller. The means from Maingard's data are definitely higher than those from the English data.

NOTES

POPULATION INDEX

THE first number of *Population Index,* a guide to current demographic materials for students, research workers and teachers appeared in January. The *Index* is published quarterly by the School of Public Affairs, Princeton University, and the Population Association of America. It continues the Association's bibliography, *Population Literature.* The current number contains two entirely new sections, Current Items and Statistics, in addition to a bibliography covering more than 400 recent books and articles. Current Items is devoted to notes on matters of special interest to students of population, such as announcements or reports of meetings and comments on new developments. The Statistics sections presents population and vital statistics for a large number of countries as well as special data for the United States. The *Index* goes to all members of the Population Association. Others wishing to receive it may write to the Office of Population Research, 20 Nassau Street, Princeton, New Jersey.

INQUIRY ON THE "SAFE PERIOD" BY THE NATIONAL COMMITTEE ON MATERNAL HEALTH, INC.

IN LINE with our interest in "medical aspects of human fertility," we are impressed by the extensive and increasing interest in and reliance upon the so-called "safe period" as a means of contraception. There is urgent need for determining, as accurately as possible, whether there exists, for the regularly menstruating woman, a predictable and reliable moiety of her cycle in which fertilization is impossible. The National Committee on Maternal Health is undertaking to collect pertinent data which, by reason of their source, will be of exceptional value.

We seek to enlist specially qualified married couples who will scrupulously keep and transmit to us — confidentially, of course — accurate and complete records of menstruation and coitus over a long period of time, several years if possible. We suggest, though not exclusively, couples of whom one or both are, say, physicians or graduate students or faculty members or research workers in biologic or other scientific departments, therefore competent to furnish trustworthy records and also scientifically interested in contributing to this investigation.

A couple such as we wish to enlist would prefer not to have a pregnancy develop during the next year or more, although if one did develop it would not be calamitous. Accordingly, the couple would observe the so-called "safe periods" as their sole means of avoiding conception. If that succeeds, and then the time comes when they desire a child, they would reverse their practice, confining coitus to occasions outside the "safe period," or they would at least restrict intercourse to the moieties of the menstrual cycle, when, theoretically, pregnancy is most likely to result, and then record how soon it does result. Needless to say, there must be no known or probable factor of involuntary sterility in either one of the couple.

The frankly experimental character of the coital practices on which these records are based, and the special qualifications of the recorders, will make these data uniquely valuable.

The committee is peculiarly fitted to collect these records. Its territory is large enough to encompass couples in number adequate for the investigation — couples who, by reason of their particular qualifications and their willingness to volunteer, must be few in any one community, no matter how large the latter may be.

On application, we shall distribute to individuals simple record forms and brief instructions easy to follow. We hope to hear from as many as possible who are reached, directly or indirectly, by this announcement. Please address National Committee on Maternal Health, Inc., New York Academy of Medicine Building, 2 East 103rd Street, New York, N. Y.

RAYMOND SQUIER, M. D.
EXECUTIVE SECRETARY
NATIONAL COMMITTEE ON MATERNAL HEALTH, INC.

RECENT LITERATURE

USEFUL IN THE STUDY OF HUMAN BIOLOGY

In this department will be noticed the books and reprints which are currently received at the Editorial Office. Publications intended for notice here should be addressed to Dr. Raymond Pearl, Department of Biology, School of Hygiene and Public Health, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

I. EVOLUTION AND GENETICS

1. *Evolution—General Principles*

DÜRKEN, B. Entwicklungsbiologie und Ganzheit. Ein Beitrag zur Neugestaltung des Weltbildes. *Leipzig and Berlin* (B. G. Teubner), 1936. Pp. vi + 207. 9 × 6 inches. RM. 6.80 (cloth); RM. 5.80 (paper). [Bibliography of 10 pages.]

GATES, R. RUGGLES. Mutations and natural selection. *American Naturalist*, Vol. 70, pp. 505-516, 1936. [Bibliography of 21 titles.]

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2. *Human Evolution*

LONDON JOURNALIST. Why be an Ape? Observations on Evolution. Preface by Admiral Sir George F. King-Hall. Illustrations by W. D. Ford. *London* (Marshall, Morgan and Scott); *Grand Rapids* (Zondervan Publishing House), 1936. Pp. 144. 7¼ × 4⅞ inches. $1.00.

WEIDENREICH, FRANZ. The Mandibles of *Sinanthropus pekinensis*: A Comparative Study. *Palaeontologia Sinica*, Series D, Volume VII. *Peking* (Geological Survey of China), 1936. Pp. 162 + 15 plates. 11¾ × 8⅞ inches (paper).

3. *Prehistory and Archaeology*

BRADY, L. F. The Arroyo of the Rio de Flag. A study of an erosion cycle. *Museum Notes* (*Museum of Northern Arizona*), Vol. 9, pp. 33-37, 1936.

CHILDE, V. GORDON. Man Makes Himself. *London* (Watts and Co.), 1936. Pp. xii + 275. 7¾ × 5 inches. 7s. 6d. net.

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4. *Genetics—General Principles*

ALVERDES, FRIEDRICH. Grundzüge der Vererbungslehre. *Leipzig* (S. Hirzel), 1935. Pp. viii + 143. 8½ × 5¾ inches. 5 marks (paper). [Bibliography of 22 titles.]

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